US009127652B2

(12) United States Patent
Kato et al.

(10) Patent No.: US 9,127,652 B2
(45) Date of Patent: Sep. 8, 2015

(54) **METHOD AND APPARATUS FOR DRIVING A POLYMER ACTUATOR TO CONTROL A LENS**

(75) Inventors: **Yusaku Kato**, Tokyo (JP); **Takehisa Ishida**, Tokyo (JP); **Nobuyuki Nagai**, Kanagawa (JP)

(73) Assignee: **Sony Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 647 days.

(21) Appl. No.: **13/205,941**

(22) Filed: **Aug. 9, 2011**

(65) **Prior Publication Data**

US 2012/0038815 A1 Feb. 16, 2012

(30) **Foreign Application Priority Data**

Aug. 16, 2010 (JP) 2010-181716

(51) **Int. Cl.**

H04N 5/225	(2006.01)
F03G 7/00	(2006.01)
G02B 7/02	(2006.01)
G02B 7/10	(2006.01)
G02B 13/00	(2006.01)
H01L 41/09	(2006.01)
H01L 41/193	(2006.01)

(52) **U.S. Cl.**

CPC ***F03G 7/005*** (2013.01); ***G02B 7/026*** (2013.01); ***G02B 7/102*** (2013.01); ***G02B 13/0025*** (2013.01); ***H01L 41/0946*** (2013.01); ***H01L 41/193*** (2013.01)

(58) **Field of Classification Search**

CPC H04N 5/2253

USPC 348/374

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0030408	A1 *	2/2005	Ito et al.	348/340
2006/0261709	A1	11/2006	Kato et al.	
2007/0108890	A1 *	5/2007	Forrest	313/504
2008/0144185	A1 *	6/2008	Wang et al.	359/665
2010/0033835	A1 *	2/2010	Heim et al.	359/683
2010/0171393	A1	7/2010	Pei et al.	

FOREIGN PATENT DOCUMENTS

CN	1967314	A	5/2007
CN	101672972	A	3/2010
JP	2006-172635	A	6/2006
JP	2006-293006	A	10/2006
JP	2008-216074	A	9/2008
JP	2011-507036	A	3/2011
KR	2005-0011243	A	1/2005
WO	WO 2009/076477	A1	6/2009
WO	WO 2011/114435	A1	9/2011

* cited by examiner

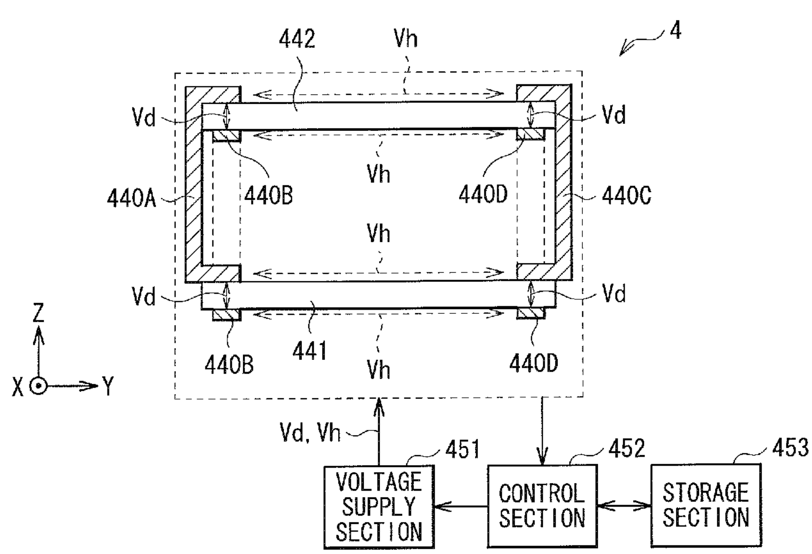
Primary Examiner — Usman Khan

(74) *Attorney, Agent, or Firm* — Wolf, Greenfield & Sacks, P.C.

(57) **ABSTRACT**

A driving unit that may improve characteristics in a low temperature environment while implementing downsizing, and a lens module as well as an image pickup device with such a driving unit are provided. The driving unit includes one or a plurality of polymer actuator elements, and a voltage supply section supplying a driving voltage and a heating voltage to the polymer actuator element.

18 Claims, 19 Drawing Sheets



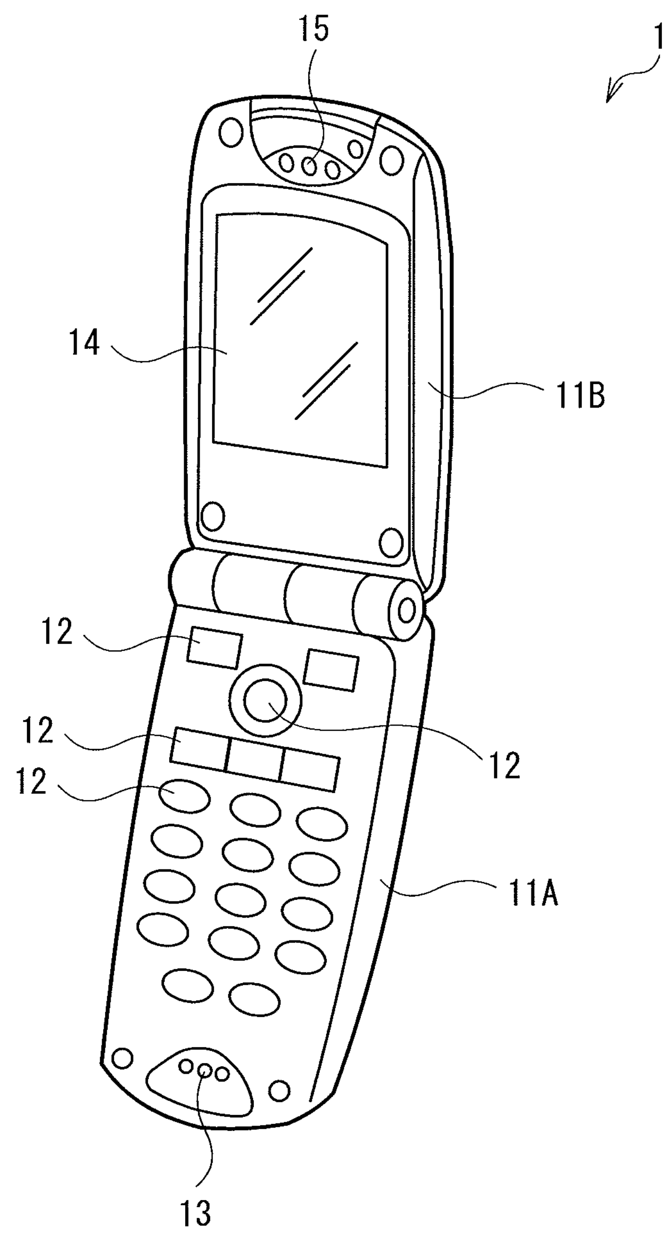


FIG. 1

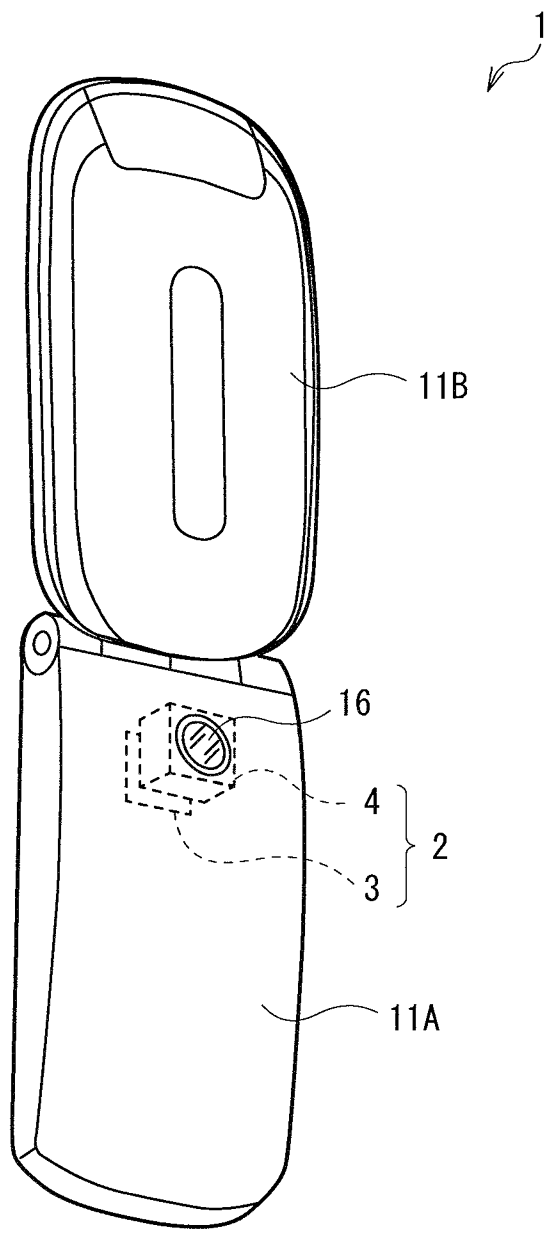


FIG. 2

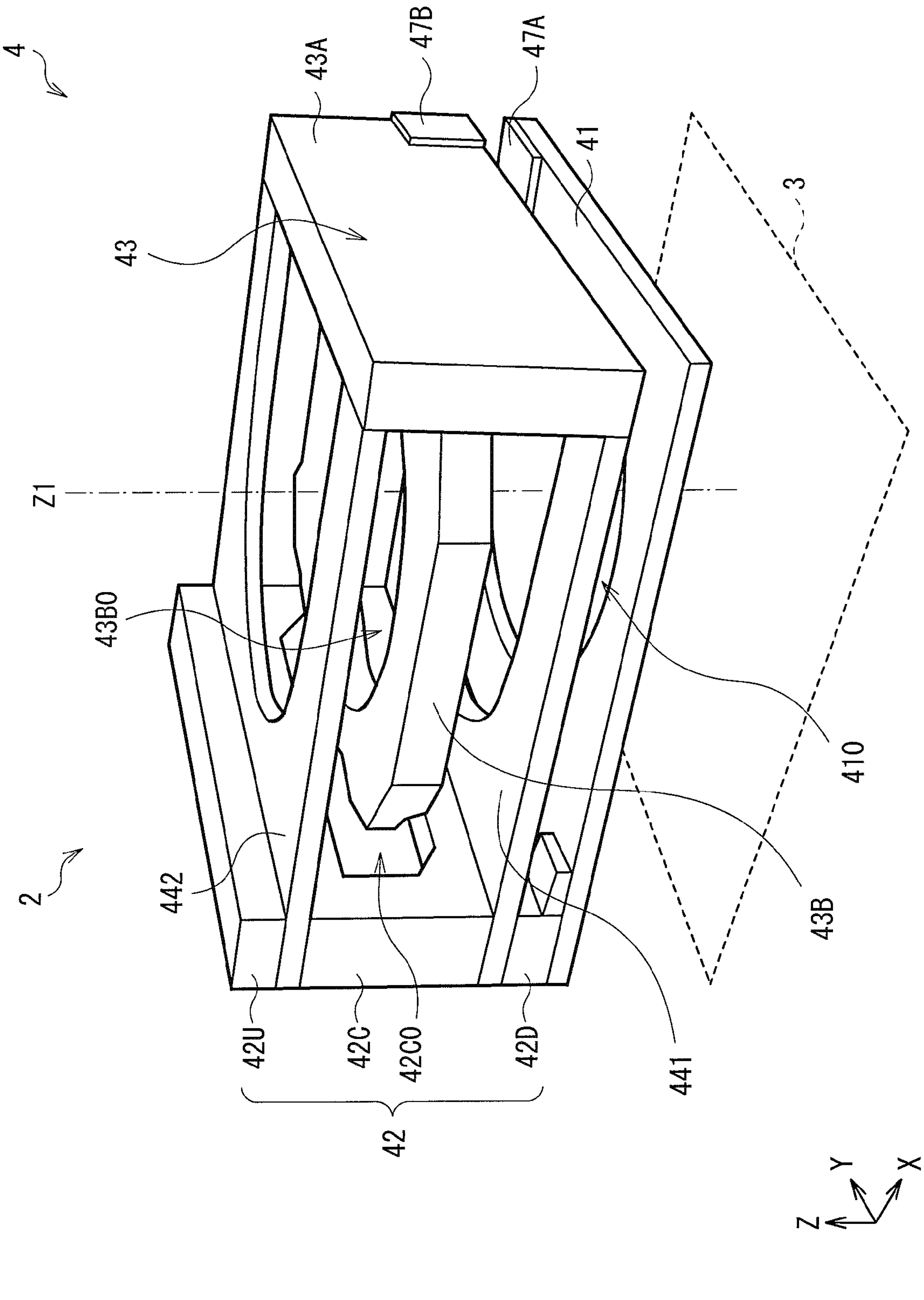

4
43A
47B
47A
41
3
43
Z1
43B0
410
43B
2
442
441
42U
42C
42C0
42D
42
Z
Y
X

FIG. 3

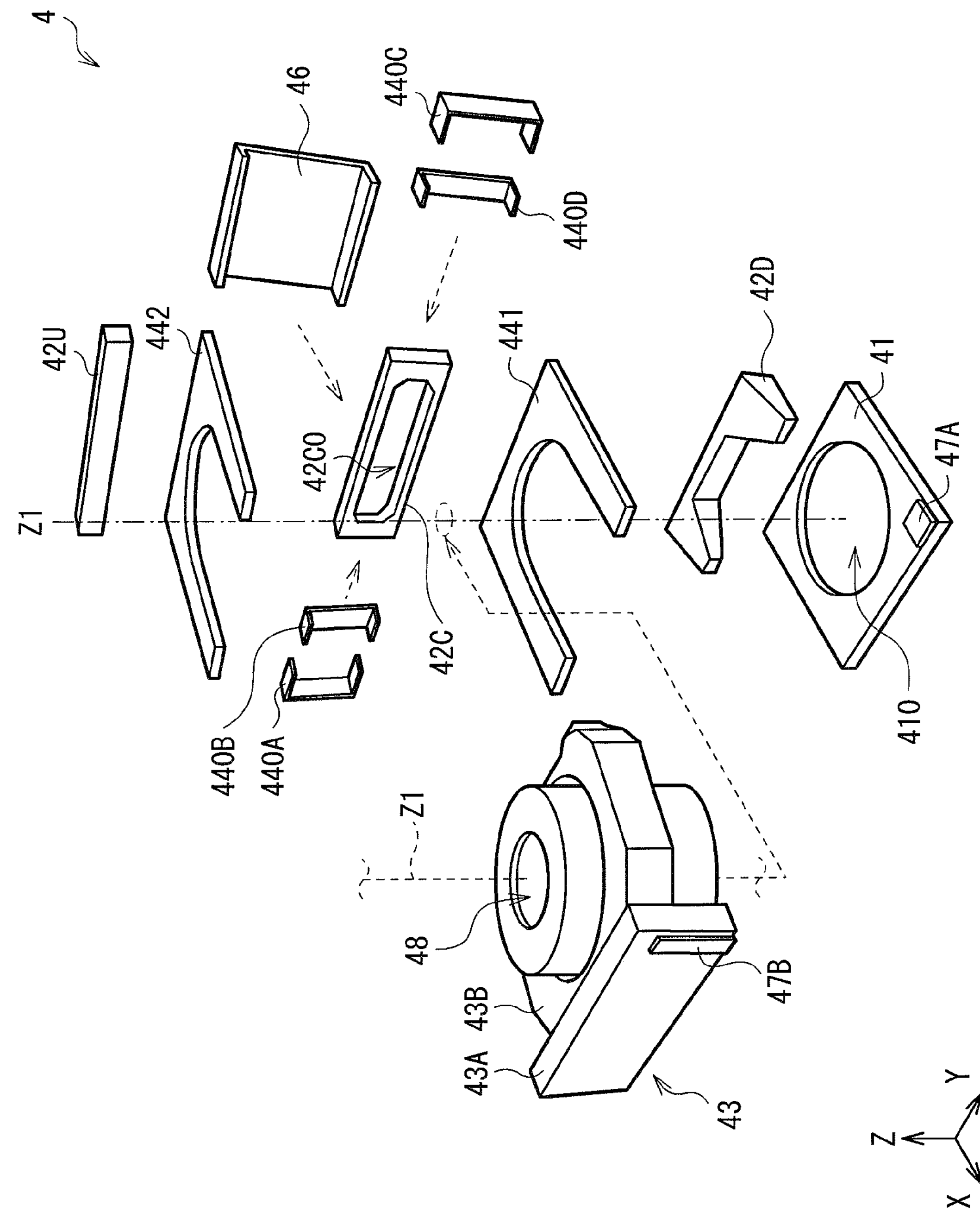

4
46
440C
440D
42U
442
42D
441
41
42C0
47A
Z1
42C
440B
440A
410
Z1
48
47B
43B
43A
43
Z
Y
X

FIG. 4

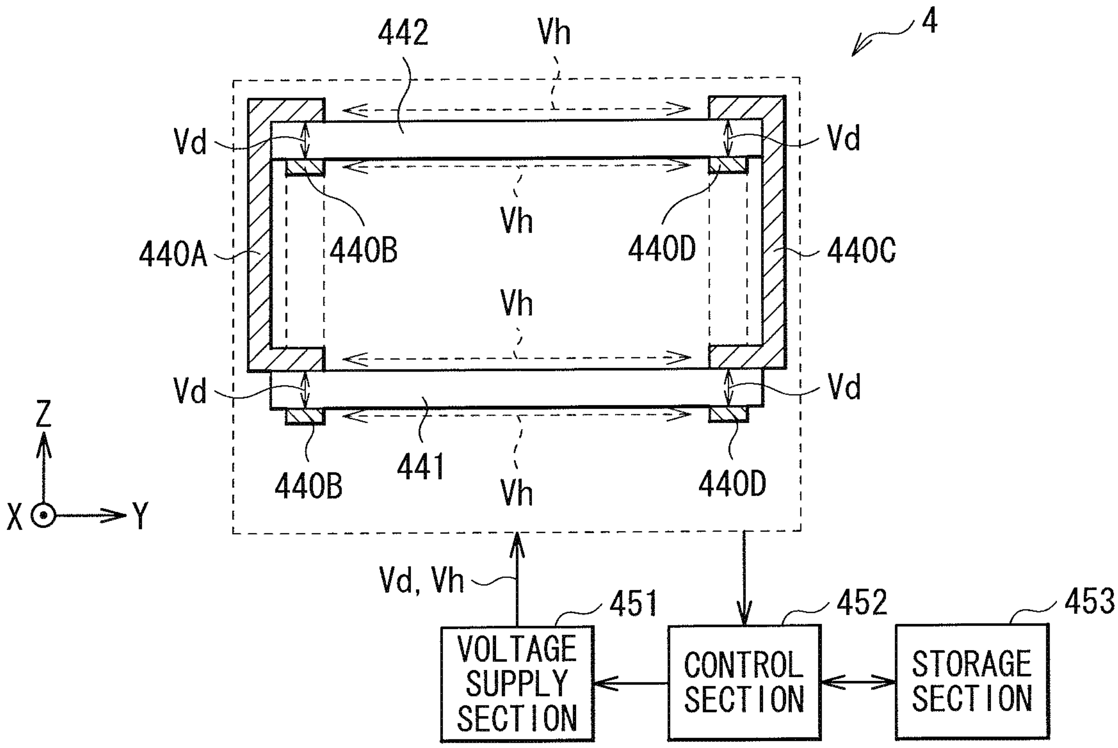

4
442
Vh
Vd
Vd
440B
Vh
440D
440A
440C
Vh
Vd
Vd
440B
441
Vh
440D
Z
X
Y
Vd, Vh
451
452
453
VOLTAGE SUPPLY SECTION
CONTROL SECTION
STORAGE SECTION

FIG. 5

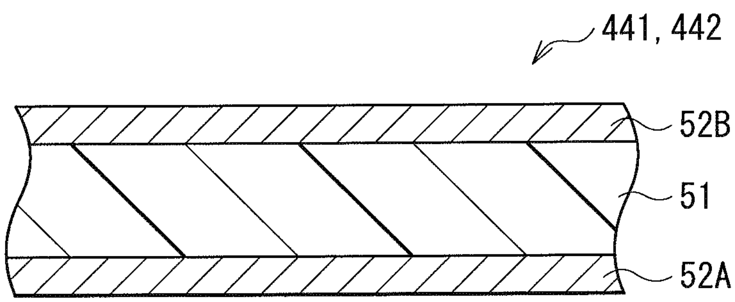

441, 442
52B
51
52A

FIG. 6

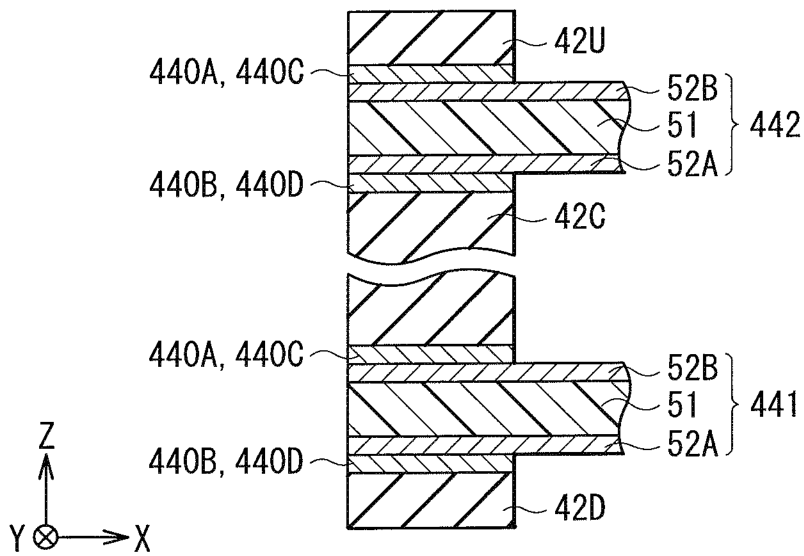


FIG. 7

FIG. 8A

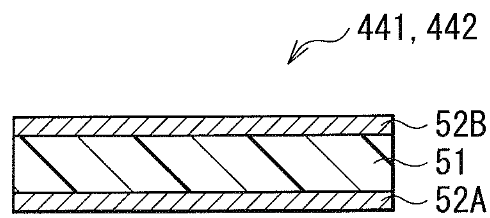


FIG. 8B

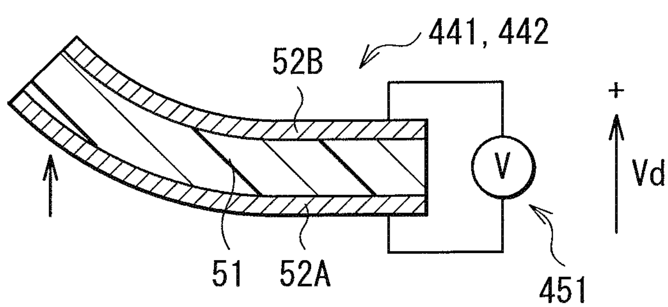


FIG. 9A

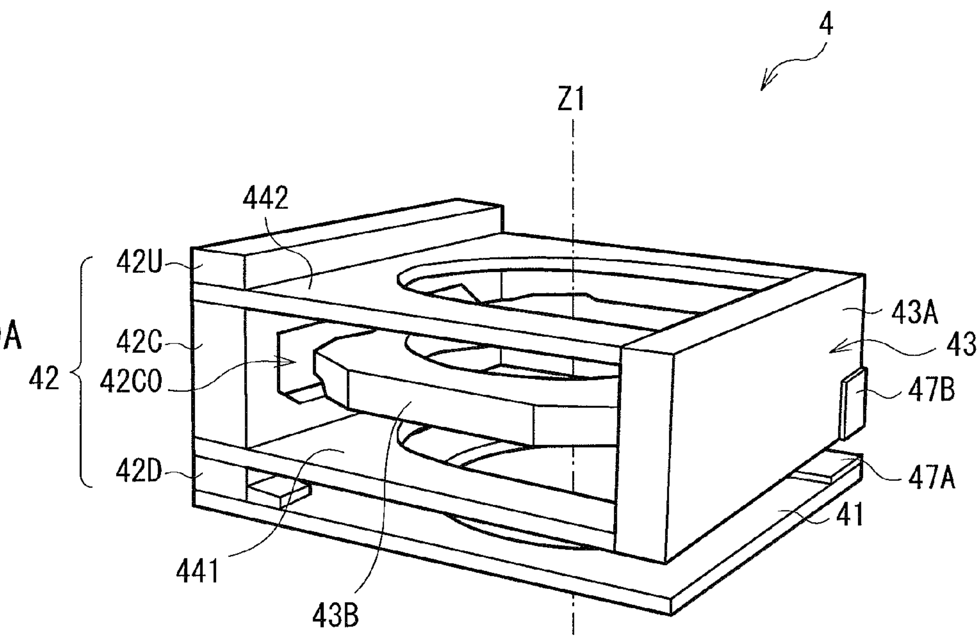
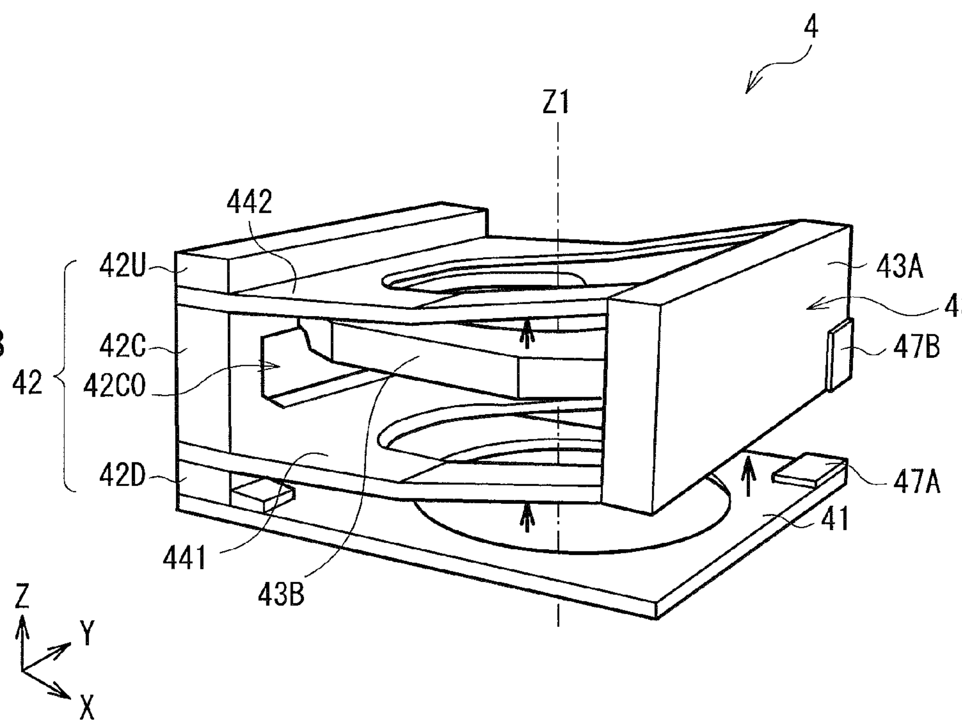

4
Z1
442
42U
42C
42CO
42
42D
441
43B
43A
43
47B
47A
41

FIG. 9B


4
Z1
442
42U
42C
42CO
42
42D
441
43B
43A
43
47B
47A
41
Z
Y
X

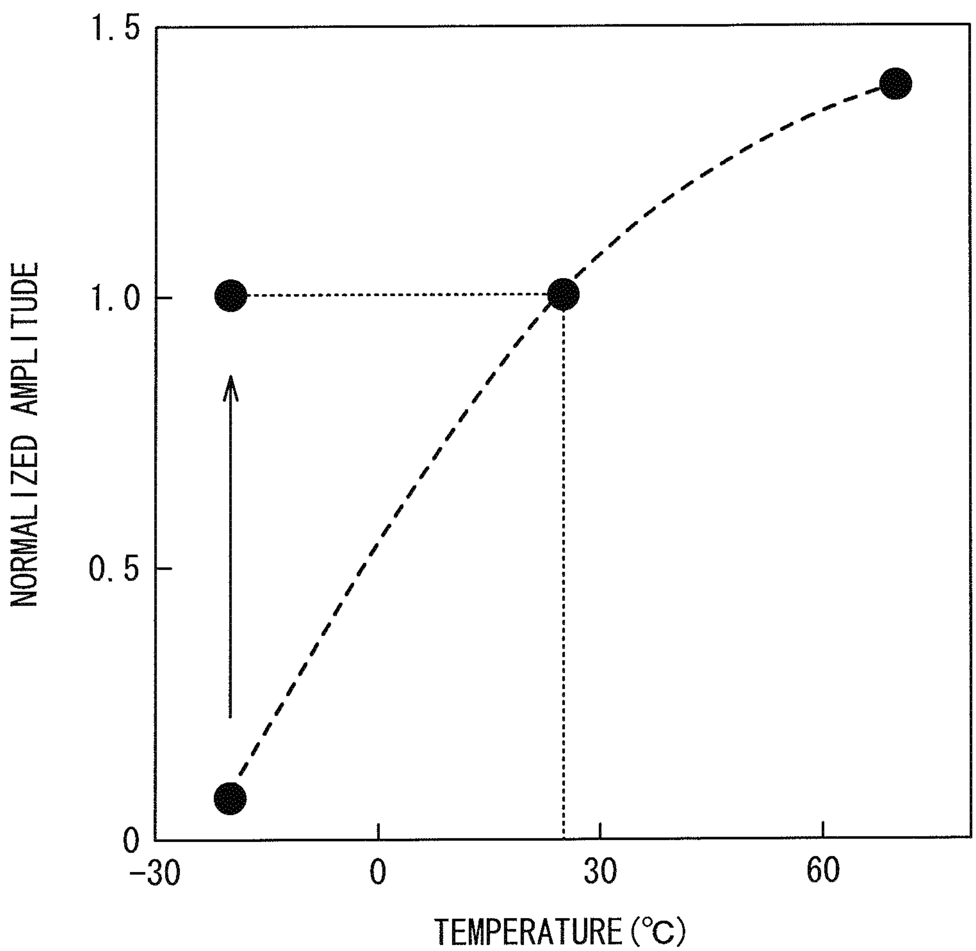


FIG. 10

FIG. 11A

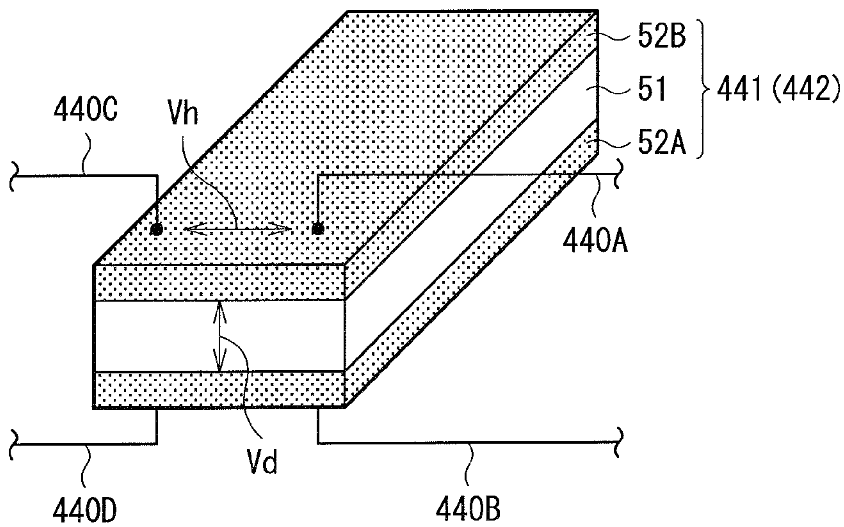
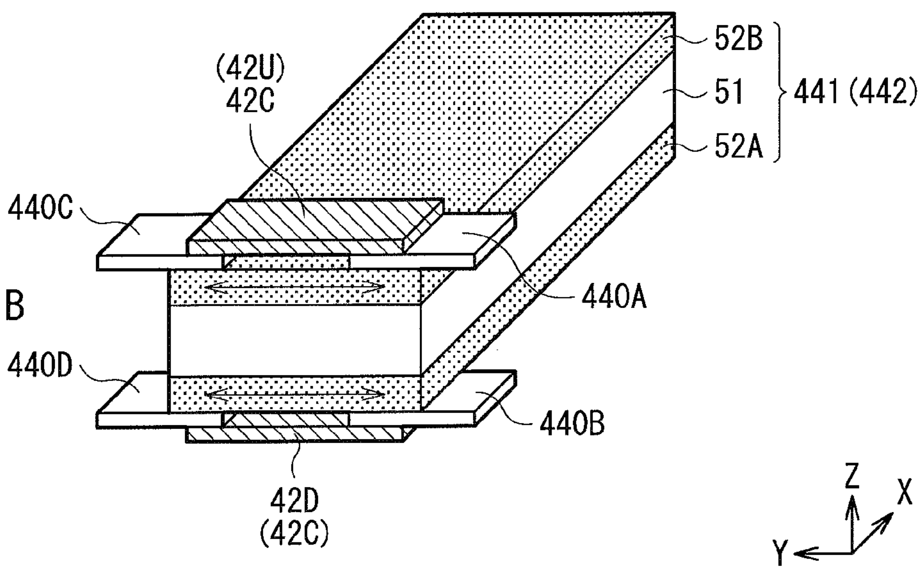
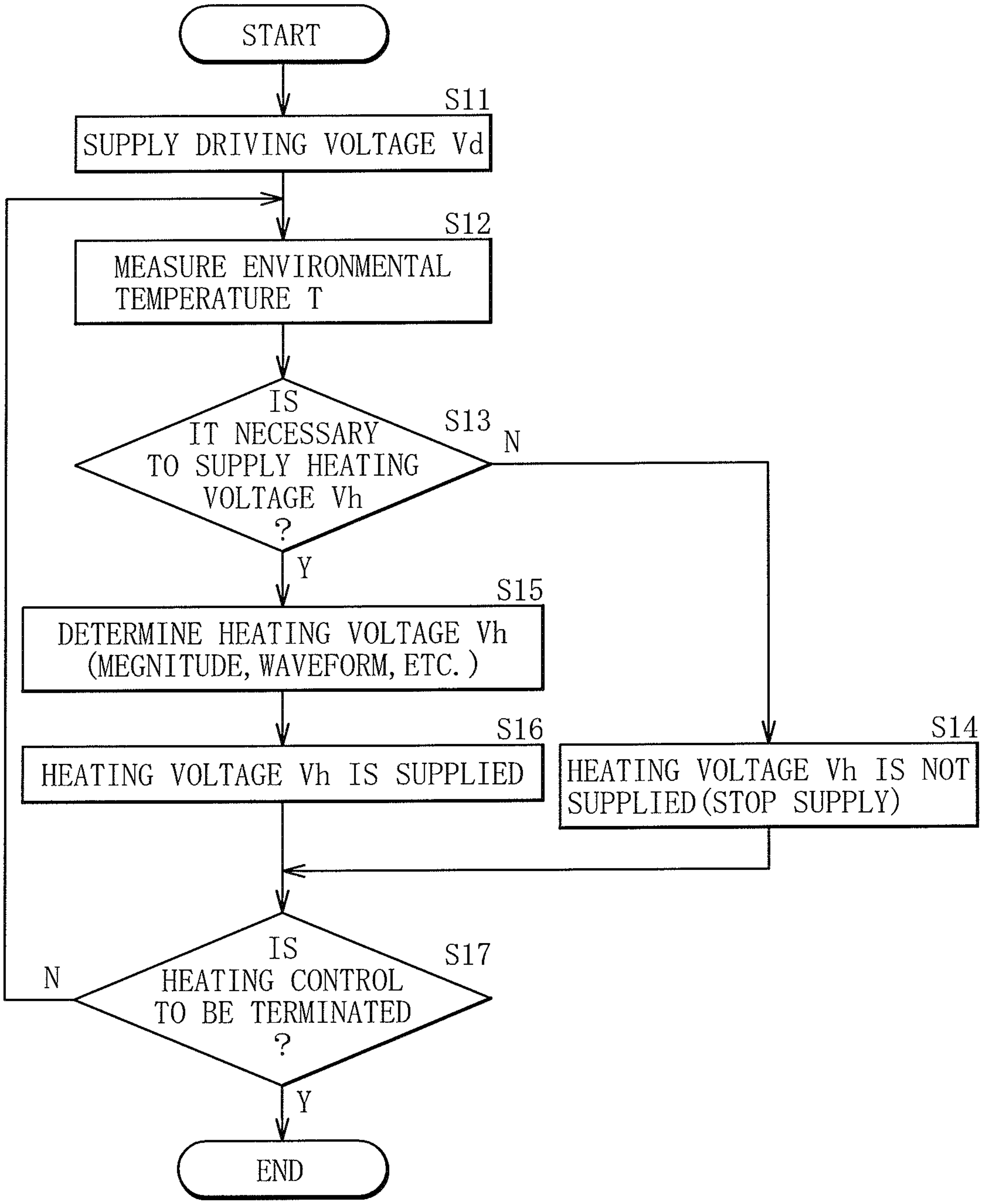


FIG. 11B





START
S11
SUPPLY DRIVING VOLTAGE Vd
S12
MEASURE ENVIRONMENTAL TEMPERATURE T
S13
IS IT NECESSARY TO SUPPLY HEATING VOLTAGE Vh ?
N
Y
S15
DETERMINE HEATING VOLTAGE Vh (MEGNITUDE, WAVEFORM, ETC.)
S16
HEATING VOLTAGE Vh IS SUPPLIED
S14
HEATING VOLTAGE Vh IS NOT SUPPLIED (STOP SUPPLY)
S17
IS HEATING CONTROL TO BE TERMINATED ?
N
Y
END

FIG. 12

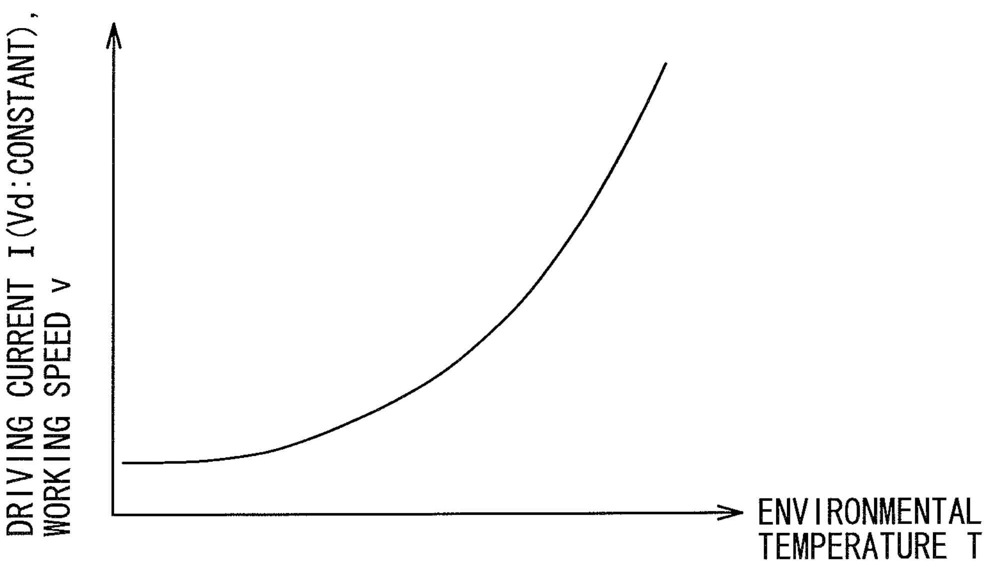

DRIVING CURRENT I (Vd:CONSTANT),
WORKING SPEED v
ENVIRONMENTAL
TEMPERATURE T

FIG. 13

FIG. 14A

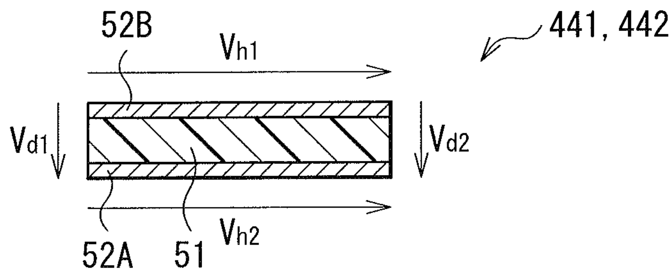


FIG. 14B

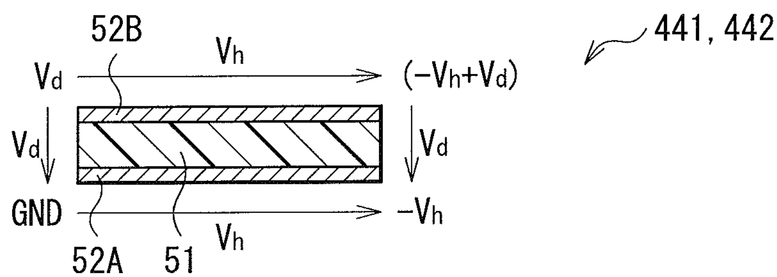


FIG. 14C

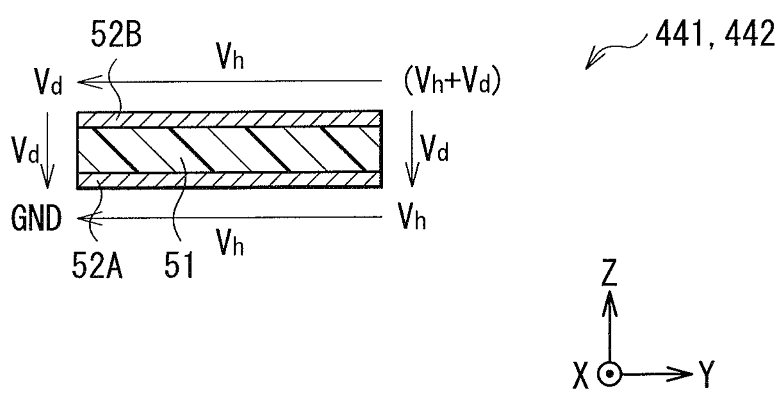


FIG. 15A

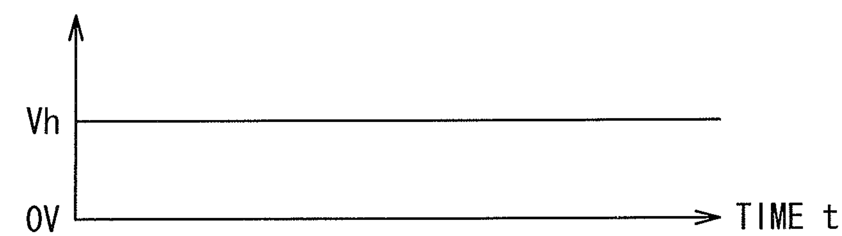
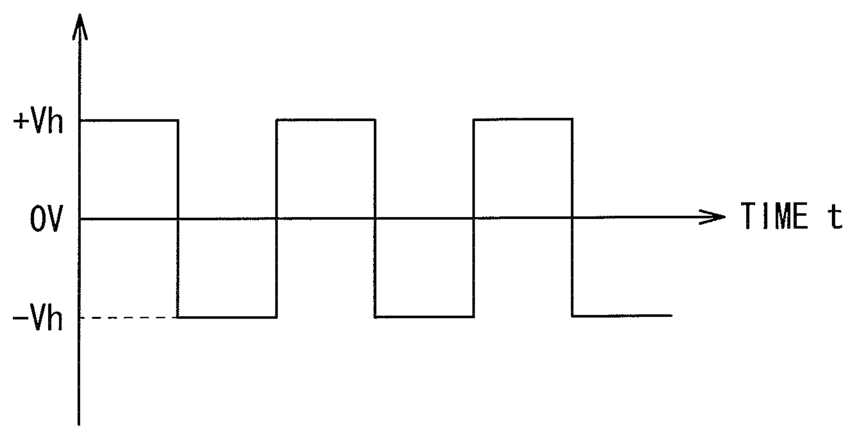


FIG. 15B



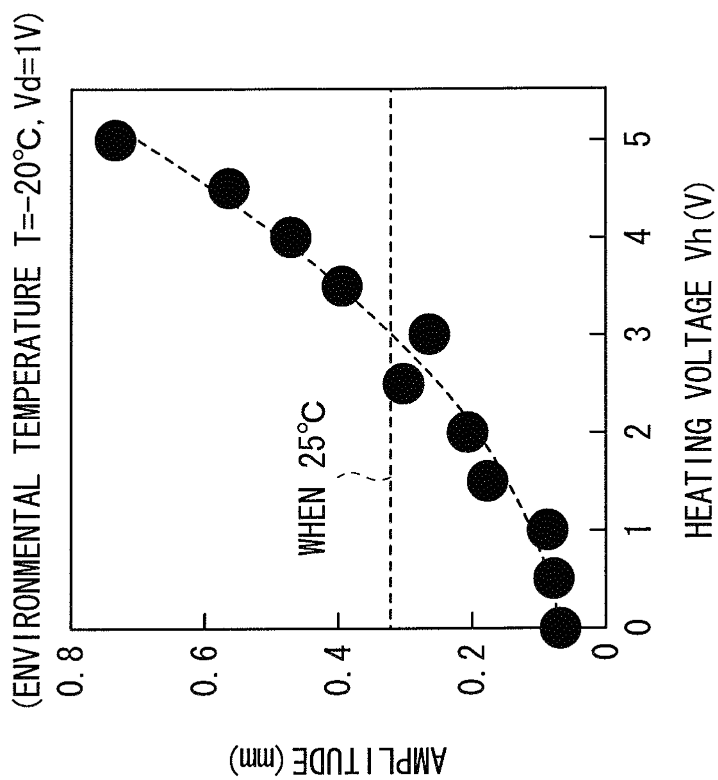


FIG. 16B

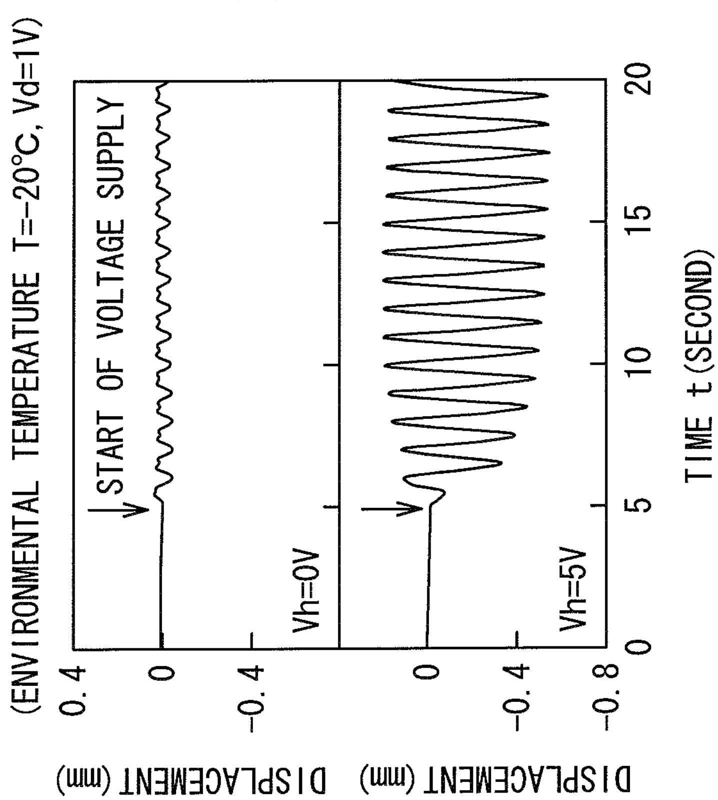


FIG. 16A

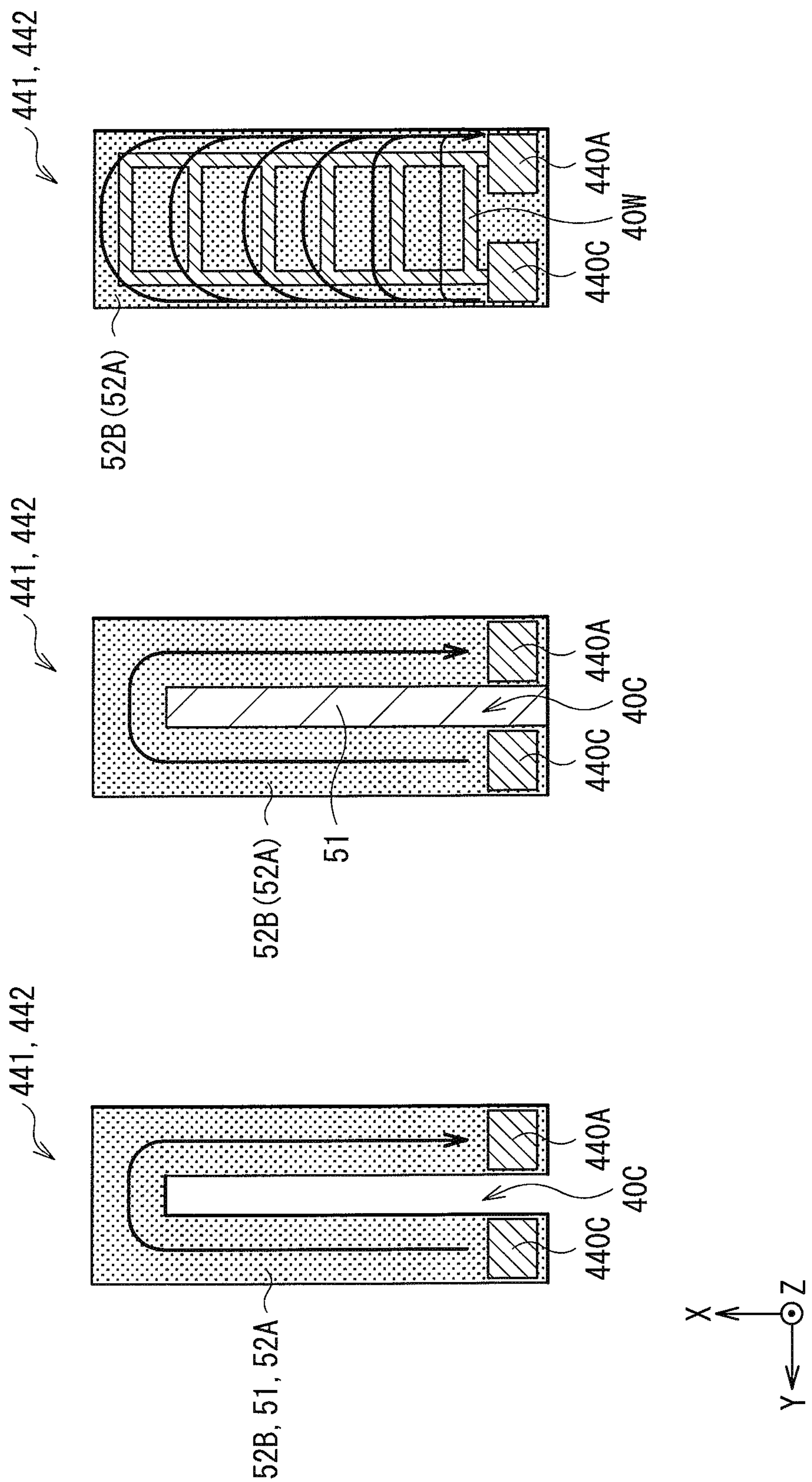


FIG. 17C

FIG. 17B

FIG. 17A

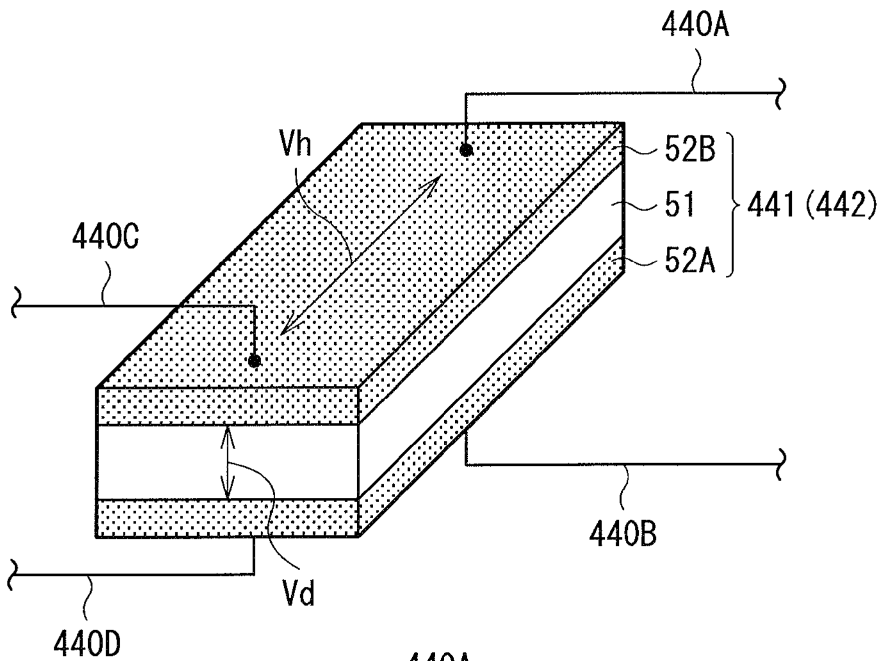


FIG. 18A

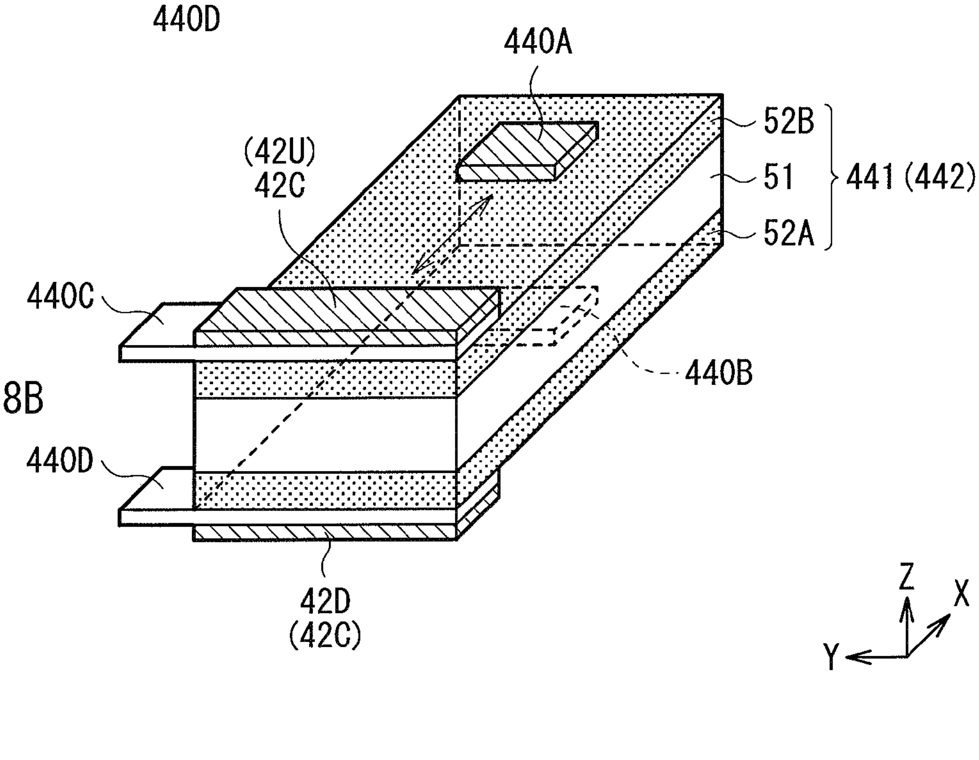


FIG. 18B

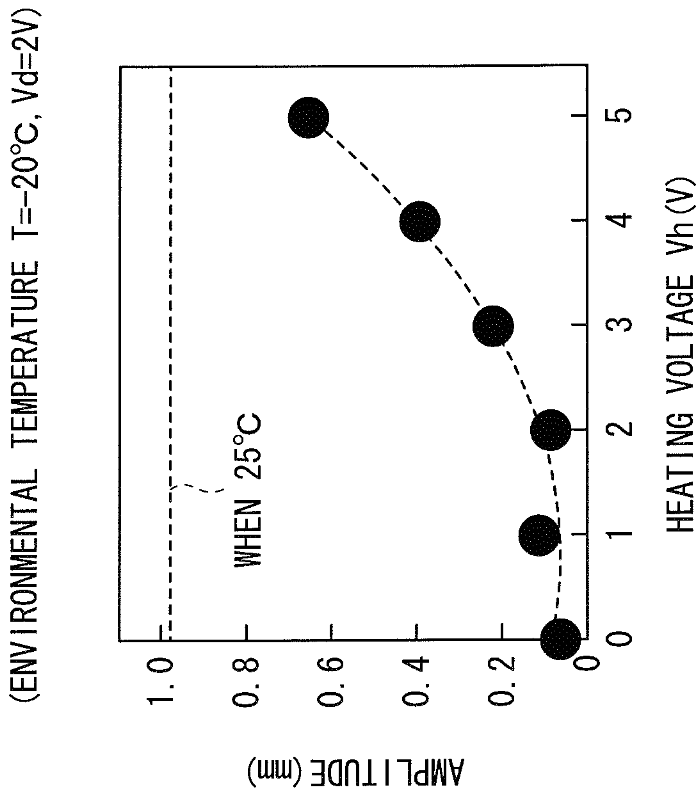


FIG. 19B

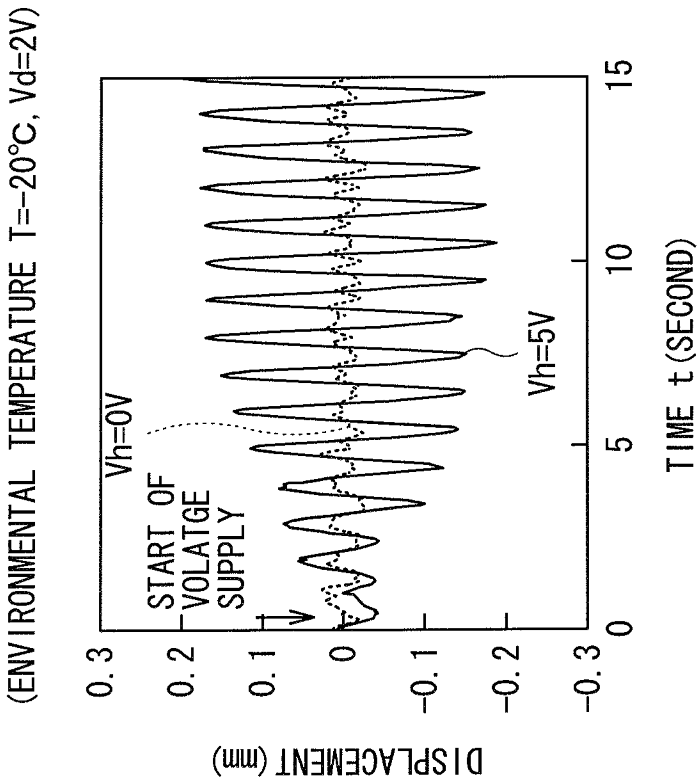


FIG. 19A

FIG. 20A

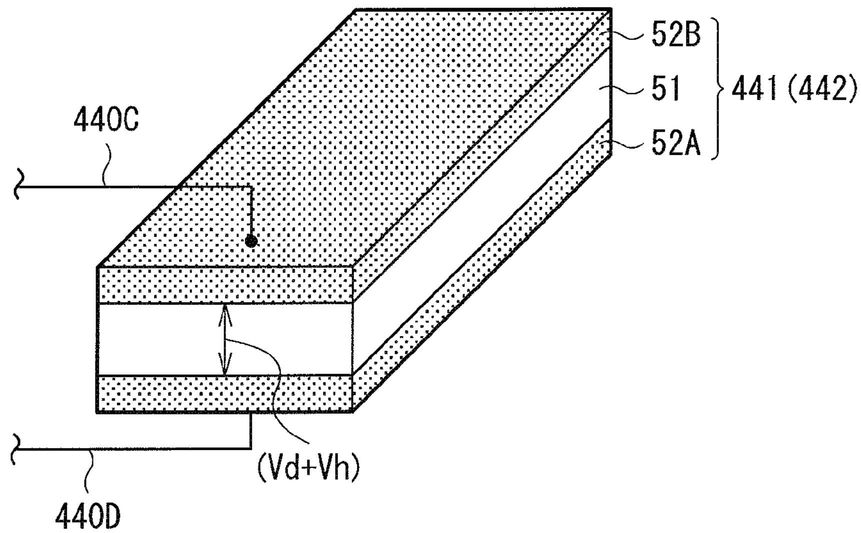


FIG. 20B

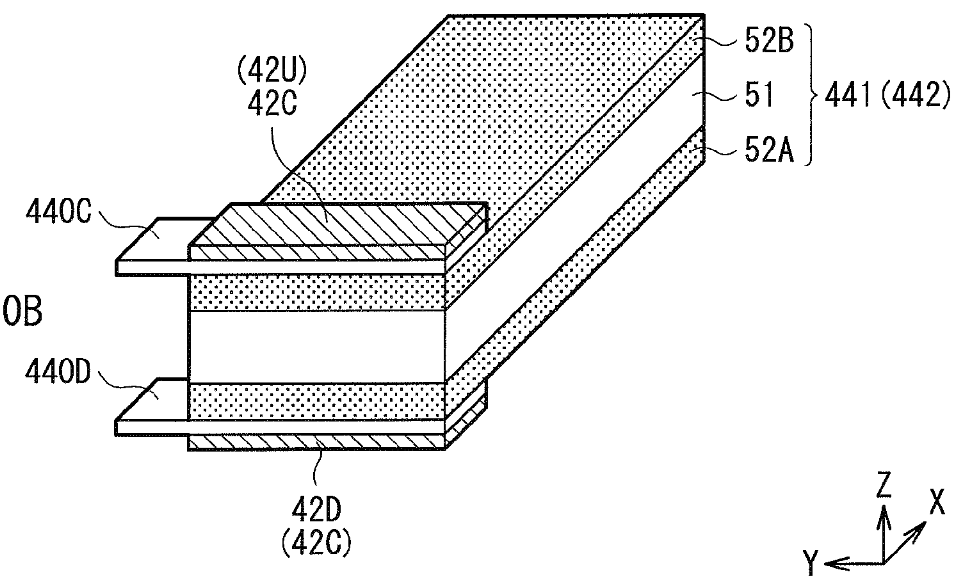


FIG. 21A

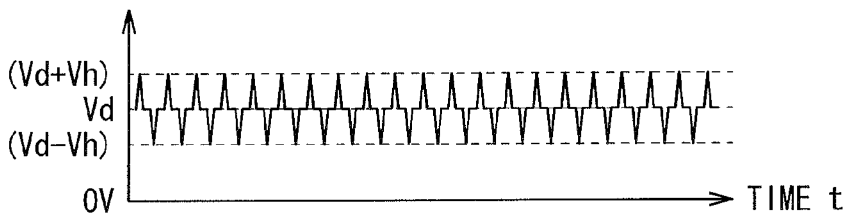
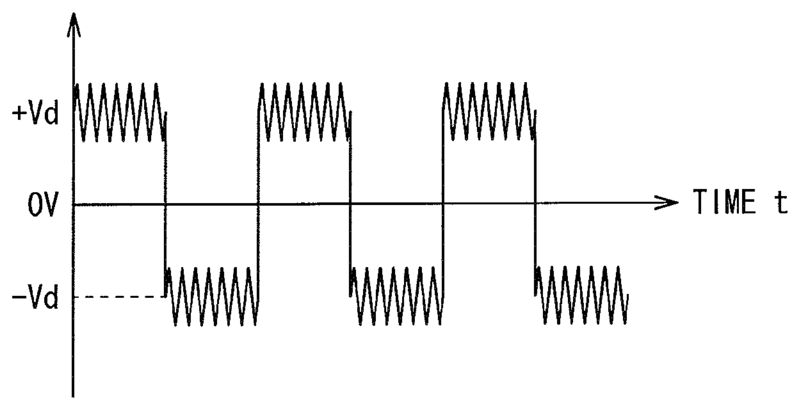


FIG. 21B



METHOD AND APPARATUS FOR DRIVING A POLYMER ACTUATOR TO CONTROL A LENS

BACKGROUND

The present disclosure relates to a driving unit using a polymer actuator element, and a lens module as well as an image pickup device with such a driving unit.

In recent years, for example, portable electronic devices such as a portable telephone, and a personal computer (PC), or a PDA (Personal Digital Assistant) have become remarkably multifunctional, and a portable electronic device equipped with a lens module thereby having an image pickup function has become common. In such a portable electronic device, focusing and zooming are performed by moving a lens in the lens module to an optical axis direction.

In general, a way of moving the lens in the lens module by using a voice coil motor or a stepping motor as a drive section is common. Meanwhile, recently, a device employing a polymer actuator element as a drive section has been developed from the viewpoint of miniaturization (see, for example, Japanese Unexamined Patent Application Publications No. 2006-293006 and No. 2006-172635). The polymer actuator element is an element in which, for example, an ion exchange resin film is interposed between a pair of electrodes. In this polymer actuator element, the ion exchange resin film is displaced in a direction orthogonal to a film surface, due to occurrence of a potential difference between the pair of electrodes.

SUMMARY

Incidentally, in such a polymer actuator element, in general, ion mobility in the ion exchange resin film mentioned above declines in a low temperature environment, compared to a room temperature environment. For this reason, in the low temperature environment, there is such a disadvantage that there occurs degradation (deterioration) in characteristics, such as a decline in the working speed of the polymer actuator element or a reduction in displacement, compared to the room temperature environment.

Thus, it is conceivable to provide a heat source (a heater or the like) outside, in order to improve the characteristics in the low temperature environment of such a polymer actuator element. However, provision of such a dedicated heat source separately makes a device configuration large (complicated).

In view of the foregoing, it is desirable to provide a driving unit that may improve characteristics in a low temperature environment while implementing downsizing, and a lens module as well as an image pickup device with such a driving unit.

According to an embodiment of the present disclosure, there is provided a driving unit including one or a plurality of polymer actuator elements, and a voltage supply section supplying a driving voltage and a heating voltage to the polymer actuator element.

Further, according to an embodiment of the present disclosure, there is provided a lens module including a lens, and the above-described driving unit driving the lens.

Furthermore, according to an embodiment of the present disclosure, there is provided an image pickup device including a lens, an image pickup element acquiring an image pickup signal of image formation by the lens, and the above-described driving unit driving the lens.

In the driving unit, the lens module, and the image pickup device according to the embodiment of the present disclosure, in addition to the driving voltage, the heating voltage is supplied to the polymer actuator element. Thus, the temperature of the element increases due to heat generation by the polymer actuator element itself, without a dedicated heat source being provided outside separately.

According to the driving unit, the lens module, and the image pickup device of the embodiment of the present disclosure, in addition to the driving voltage, the heating voltage is supplied to the polymer actuator element. Therefore, it is possible to increase the temperature of the element by heat generation of the polymer actuator element itself, and improve the working speed and the like of the element in a low temperature environment, without providing an external dedicated heat source separately. Accordingly, it is possible to improve characteristics in the low temperature environment, while implementing downsizing.

It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the technology as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and, together with the specification, serve to explain the principles of the technology.

FIG. **1** is a perspective diagram illustrating a configurational example of an electronic device with an image pickup device according to an embodiment of the present disclosure.

FIG. **2** is a perspective diagram illustrating the electronic device illustrated in FIG. **1**, viewed from a different direction.

FIG. **3** is a perspective diagram illustrating a configurational example of a main part of an image pickup device depicted in FIG. **2**.

FIG. **4** is an exploded perspective view illustrating a lens module depicted in FIG. **3**.

FIG. **5** is a schematic diagram illustrating a detailed arrangement configurational example of each fixed electrode illustrated in FIG. **4**, together with each control block.

FIG. **6** is a cross-sectional diagram illustrating a detailed configurational example of a polymer actuator element.

FIG. **7** is a cross-sectional diagram illustrating a detailed configuration of part of the polymer actuator element, a fixing member, and the fixed electrode.

FIGS. **8**A and **8**B are cross-sectional schematic diagrams for explaining basic operation of the polymer actuator element.

FIGS. **9**A and **9**B are perspective diagrams for explaining operation of the lens module illustrated in FIG. **3**.

FIG. **10** is a characteristic diagram illustrating an example of a temperature characteristic of the polymer actuator element.

FIGS. **11**A and **11**B are schematic perspective diagrams for explaining a technique of applying a driving voltage and a heating voltage according to the embodiment.

FIG. **12** is a flowchart illustrating an example of a technique of heating the polymer actuator element according to the embodiment.

FIG. **13** is a characteristic diagram illustrating an example of a relationship between an environmental temperature and a driving current or a working speed in the polymer actuator element.

FIGS. **14**A to **14**C are schematic diagrams for explaining a relationship between the driving voltage and the heating voltage.

FIGS. **15**A and **15**B are timing charts each illustrating a waveform example of the heating voltage according to the embodiment.

FIGS. **16**A and **16**B are characteristic diagrams illustrating an effect of applying a heating voltage according to an example of the embodiment.

FIGS. **17**A to **17**C are schematic diagrams each illustrating a configurational example of a polymer actuator element and a fixed electrode according to a modification 1.

FIGS. **18**A and **18**B are schematic perspective diagrams for explaining a technique of applying a driving voltage and a heating voltage according to a modification 2.

FIGS. **19**A and **19**B are characteristic diagrams illustrating an effect of applying a heating voltage according to an example of the modification 2.

FIGS. **20**A and **20**B are schematic perspective diagrams for explaining a technique of applying a driving voltage and a heating voltage according to a modification 3.

FIGS. **21**A and **21**B are timing charts each illustrating a waveform example of the driving voltage and the heating voltage according to the modification 3.

DETAILED DESCRIPTION OF EMBODIMENTS

An embodiment of the present disclosure will be described below in detail with reference to the drawings. Incidentally, the description will be provided in the following order.

1. Embodiment (an example in which a heating voltage is selectively supplied to a fixed side in an electrode film of a polymer actuator element)
2. Modifications

Modification 1 (an example 1 in which a heating voltage is supplied from a fixed side along a movable side in an electrode film of a polymer actuator element)

Modification 2 (an example 2 in which a heating voltage is supplied from a fixed side along a movable side in an electrode film of a polymer actuator element)

Modification 3 (an example in which a heating voltage is supplied between electrode films of a polymer actuator element)

[Embodiment]

Schematic Structure of Electronic Device with Image Pickup Device

FIG. **1** and FIG. **2** are perspective diagrams illustrating a schematic structure of a portable telephone (a portable telephone **1**) with an image pickup function, as an example of an electronic device with an image pickup device (an image pickup device **2** to be described later) according to an embodiment of the present disclosure. In this portable telephone **1**, two housings **11**A and **11**B are foldably coupled together through a hinge mechanism not illustrated.

As illustrated in FIG. **1**, in a surface on one side of the housing **11**A, various operation keys **12** are disposed, and a microphone **13** is disposed below the operation keys **12**. The operation keys **12** are intended to receive predetermined operation by a user and thereby input information. The microphone **13** is intended to input voice of the user during a call and the like.

As illustrated in FIG. **1**, a display section **14** using a liquid-crystal display panel or the like is disposed in a surface on one side of the housing **11**B, and a speaker **15** is disposed at an upper end thereof. The display section **14** displays various kinds of information such as a radio-wave receiving status, a remaining battery, a telephone number of a party on the other end of the line, contents (telephone numbers, names, and the like of other parties) recorded as a telephone book, an outgoing call history, an incoming call history, and the like, for example. The speaker **15** is intended to output the voice of a party on the other end of the line during a call and the like.

As illustrated in FIG. **2**, a cover glass **16** is disposed in a surface on the other side of the housing **11**A, and the image pickup device **2** is provided at a position corresponding to the cover glass **16** in the housing **11**A. This image pickup device **2** is configured to include a lens module **4** disposed on an object side (the cover glass **16** side), and an image pickup element **3** disposed on an image pickup side (inside of the housing **11**A). The image pickup element **3** is an element that obtains an image pickup signal of image formation by a lens (a lens **48** to be described later) in the lens module **4**. This image pickup element **3** is, for example, an image sensor mounted with a Charge Coupled Device (CCD), a Complementary Metal Oxide Semiconductor (CMOS), or the like.

(Configuration of Image Pickup Device **2** and Lens Module **4**)

FIG. **3** is a perspective diagram illustrating a configuration of a main part of the image pickup device **2**, and FIG. **4** is an exploded perspective diagram illustrating a configuration of the lens module **4** in this image pickup device **2**. Further, FIG. **5** is a schematic diagram illustrating a detailed arrangement configurational example of each of fixed electrodes (fixed electrodes **440**A, **440**B, **440**C, and **440**D to be described later) in this lens module **4**, together with each control block.

As illustrated in FIG. **3** and FIG. **4**, the lens module **4** includes a support member **41**, a polymer actuator element **441**, a lens holding member **43**, the lens **48**, and a polymer actuator element **442**, sequentially from the image side (the image pickup element **3** side) to the object side along an optical axis Z1 (in the normal direction of a Z-axis). It is to be noted that in FIG. **3**, illustration of the lens **48** is omitted. The lens module **4** further includes, as illustrated in FIG. **4**, a fixing member **42**, the fixed electrodes **440**A, **440**B, **440**C, and **440**D, a presser member **46**, and Hall elements **47**A and **47**B. This lens module **4** further includes, as illustrated in FIG. **5**, a voltage supply section **451**, a control section **452**, and a storage section **453**. It is to be noted that a combination of these members of the lens module **4** excluding the lens **48** corresponds to a specific example of "the driving unit" (lens driving unit) according to the embodiment of the present disclosure.

The support member **41** is a base member (base substrate) to support the entire lens module **4**, and is made of, for example, a hard resin material such as a liquid crystal polymer.

The fixing member **42** is a member to fix one end of each of the polymer actuator elements **441** and **442**, and is made of, for example, a hard resin material such as a liquid crystal polymer. This fixing member **42** includes three members; a lower fixing member **42**D, a central (middle) fixing member **42**C, and an upper fixing member **42**U, which are arranged from the image side (a lower part in FIG. **3** and FIG. **4**) to the object side (an upper part). One end of the polymer actuator element **441** and one end of each of the fixed electrodes **440**A, **440**B, **440**C, and **440**D are disposed to be interposed between the lower fixing member **42**D and the central fixing member **42**C. On the other hand, one end of the polymer actuator element **442** and the other end of each of the fixed electrodes **440**A, **440**B, **440**C, and **440**D are disposed to be interposed between the central fixing member **42**C and the upper fixing member **42**U. In addition, an opening **42C0** to partially hold a part of the lens holding member **43** (a part of a holding section **43**B to be described later) is formed in the central fixing member **42**C. This allows the part of the lens holding member **43** to move in this opening **42C0**, making it possible to utilize space effectively, thereby downsizing the lens module **4**.

The lens holding member **43** is a member to hold the lens **48**, and is made of, for example, a hard resin material such as a liquid crystal polymer. The lens holding member **43** is disposed so that a center thereof is on the optical axis Z**1**. This lens holding member **43** includes the holding section **43**B shaped like a ring and holing the lens **48**, and a connection section **43**A supporting the holding section **43**B and connecting (linking) the holding section **43**B and the other end of each of the polymer actuator elements **441** and **442** to each other, at an end. Specifically, here, four corners of the connection section **43**A and two pairs of projections in the polymer actuator elements **441** and **442** are connected. In addition, the holding section **43**B is disposed between driving surfaces to be described later in the pair of polymer actuator elements **441** and **442**.

Each of the Hall elements **47**A and **47**B is an element used to detect a movement (displacement) of the lens holding member **43**, and is, for example, a combination of a Hall element and a magnet.

Each of the fixed electrodes **440**A, **440**B, **440**C, and **440**D is an electrode to supply a voltage from a voltage applier (the voltage supply section **451** to be described later) to electrode films (electrode films **52**A and **52**B) in the polymer actuator elements **441** and **442** to be described later. Each of the fixed electrodes **440**A, **440**B, **440**C, and **440**D is made of, for example, gold (Au), gilt metal, or the like, and here, is shaped like a letter U as illustrated in FIG. **4** and FIG. **5**. Further, each of the fixed electrodes **440**A, **440**B, **440**C, and **440**D holds a top and a bottom (surfaces on both sides along the Z-axis direction) of the central fixing member **42**C. This makes it possible to apply the same voltages in parallel with a small number of wirings to the pair of polymer actuator elements **441** and **442**. Furthermore, in a case where the fixed electrodes **440**A, **440**B, **440**C, and **440**D are made of a gilt metallic material, it is possible to prevent deterioration of contact resistance caused by surface oxidation or the like.

Here, as illustrated in FIG. **5**, the fixed electrode **440**A is disposed on one end side (the left side in the figure) along a Y-axis direction in the polymer actuator elements **441** and **442**, to contact a top surface of each of them. The fixed electrode **440**C is disposed on the other end side (the right side in the figure) along the Y-axis direction in the polymer actuator elements **441** and **442**, to contact the top surface of each of them. Meanwhile, the fixed electrode **440**B is disposed on the one end side along the Y-axis direction in the polymer actuator elements **441** and **442**, to contact an undersurface of each of them. The fixed electrode **440**D is disposed on the other end side along the Y-axis direction in the polymer actuator elements **441** and **442**, to contact the undersurface of each of them. As illustrated in the figure, driving voltages Vd for driving (operating) the polymer actuator elements **441** and **442** are supplied from the voltage supply section **451**, which will be described below, each of between the fixed electrodes **440**A and **440**B and between the fixed electrodes **440**C and **440**D. On the other hand, heating voltages Vh for heating (causing generation of heat) the polymer actuator elements **441** and **442** are supplied from the voltage supply section **451**, each of between the fixed electrodes **440**A and **440**C and between the fixed electrodes **440**B and **440**D. Here, it is desirable that each of a distance between the fixed electrodes **440**A and **440**C and a distance between the fixed electrodes **440**B and **440**D to which the heating voltages Vh are applied, be sufficiently longer than the thickness (the length in the Z-axis direction) of each of the polymer actuator elements **441** and **442**. This is to prevent an electric field (an oblique field) from being generated along a slanting direction in a cross section of each of the polymer actuator elements **441** and **442**. It is to be noted that a technique of heating the polymer actuator elements **441** and **442** using this heating voltage Vh will be described later in detail.

The voltage supply section **451** illustrated in FIG. **5** supplies, as described above, the driving voltage Vd and the heating voltage Vh to the polymer actuator elements **441** and **442**, via the fixed electrodes **440**A, **440**B, **440**C, and **440**D. Specifically, in the present embodiment in particular, as illustrated in the figure, the voltage supply section **451** supplies the driving voltage Vd along a thickness direction of each of the polymer actuator elements **441** and **442** (between the pair of electrode films **52**A and **52**B to be described later). On the other hand, the voltage supply section **451** supplies the heating voltage Vh along an extending direction of each of the polymer actuator elements **441** and **442** (an intra-film direction of each of the electrode films **52**A and **52**B to be described later). A technique of supplying the driving voltage Vd and the heating voltage Vh will be described later in detail.

Although details will be described later, the control section **452** determines whether or not to supply the heating voltage Vh, as well as the magnitude, waveform, and the like of the heating voltage Vh at the time of supplying, based on an environmental temperature (an environmental temperature T) detected directly or indirectly. Such a control section **452** is configured by using, for example, a microcomputer or the like. Control operation of this control section **452** will be described later in detail.

The storage section **453** is a memory holding beforehand data (such as characteristic data indicating a relationship between the environmental temperature T and a driving current I or a working speed v, which will be described later) used at the time of the control operation by the control section **452** described above. As such a storage section **453**, various types of storage sections may be used.

(Polymer Actuator Elements **441** and **442**)

The polymer actuator elements **441** and **442** each have a driving surface orthogonal to the optical axis Z**1** of the lens **48** (a driving surface on an X-Y plane), and are disposed so that the driving surfaces face each other along this optical axis Z**1**. Each of the polymer actuator elements **441** and **442** is intended to drive the lens holding member **43** (and the lens **48**) along the optical axis Z**1**.

Each of these polymer actuator elements **441** and **442** has, as illustrated in FIG. **6**, a sectional structure in which the pair of electrode films **52**A and **52**B adhere to both sides of an ionic conductive polymer compound film **51** (hereinafter merely referred to as the polymer compound film **51**). In other words, each of the polymer actuator elements **441** and **442** has the pair of electrode films **52**A and **52**B, and the polymer compound film **51** inserted between these electrode films **52**A and **52**B. The polymer actuator elements **441** and **442** and the electrode films **52**A and **52**B may be covered by an insulating protective film made of a material having high elasticity (for example, polyurethane) in the periphery thereof.

Here, as indicated by a cross section (a Z-X cross section) in FIG. **7**, in the polymer actuator element **441**, the electrode film **52**A is electrically connected to the fixed electrodes **440**B and **440**D on the lower fixing member **42**D side, and the electrode film **52**B is electrically connected to the fixed electrodes **440**A and **440**C on the central fixing member **42**C side. On the other hand, in the polymer actuator element **442**, the electrode film **52**A is electrically connected to the fixed electrodes **440**B and **440**D on the central fixing member **42**C side, and the electrode film **52**B is electrically connected to the fixed electrodes **440**A and **440**C on the upper fixing member **42**U side. Although not illustrated in FIG. **7**, each member and electrode, from the fixed electrodes **440**B and **440**D on the lower fixing member **42**D side to the fixed electrodes **440**A and **440**C on the upper fixing member **42**U side, is fixed as being clamped by the presser member **46** (flat spring) illustrated in FIG. **4** with constant pressure. This prevents the polymer actuator elements **441** and **442** from being destroyed even when a large force is exerted thereon, and allows stable electrical connection even when these polymer actuator elements **441** and **442** are deformed.

The polymer compound film **51** is configured to be curved by a predetermined potential difference occurring between the electrode films **52**A and **52**B. This polymer compound film **51** is impregnated with an ionic substance. The "ionic substance" here means a substance including cations and/or anions and a polar solvent, or a substance including liquid cations and/or anions. For example, as the former, there is a substance in which a polar solvent is solvated in cations and/or anions, and as the latter, there is an ionic liquid.

As a material of the polymer compound film **51**, there is, for example, an ion exchange resin in which a fluorocarbon resin or a hydrocarbon system is a skeleton. As the ion exchange resin, it is preferable to use a cation exchange resin when a cationic substance is impregnated, and use an anion exchange resin when an anionic substance is impregnated.

As the cation exchange resin, there is, for example, a resin into which an acidic group such as a sulfonate group or a carboxyl group is introduced. Specifically, the cation exchange resin is a polyethylene having an acidic group, a polystyrene having an acidic group, a fluorocarbon resin having an acid group, or the like. Above all, a fluorocarbon resin having a sulfonate group or a carboxylic acid group is preferable as the cation exchange resin, and there is, for example, Nafion (made by E. I. du Pont de Nemours and Company).

It is desirable that the cationic substance impregnated in the polymer compound film **51** be a substance including metal ions and water, a substance including organic cations and water, or an ionic liquid. As the metal ion, there is, for example, light metal ion such as sodium ion (Na^+), potassium ion (K^+), lithium ion (Li^+), or magnesium ion (Mg^{2+}). Further, as the organic cation, there is, for example, alkylammonium ion. These cations exist as a hydrate in the polymer compound film **51**. Therefore, in a case where the polymer compound film **51** is impregnated with the cationic substance including cations and water, it is desirable to seal the whole in order to suppress volatilization of the water, in the polymer actuator elements **441** and **442**.

The ionic liquid is also called ambient temperature molten salt, and includes cations and anions having low combustion and volatility. As the ionic liquid, there is, for example, an imidazolium ring system compound, a pyridinium ring system compound, or an aliphatic compound.

Above all, it is preferable that the cationic substance be the ionic liquid. This is because the volatility is low, and the polymer actuator elements **441** and **442** work well even in a high-temperature atmosphere or in a vacuum.

Each of the electrode films **52**A and **52**B facing each other across the polymer compound film **51** interposed therebetween includes one or more than one kind of conductive material. It is preferable that each of the electrode films **52**A and **52**B be a film in which particles of a conductive material powder are bound by an ionic conductive polymer. This is because flexibility of the electrode films **52**A and **52**B increases. A carbon powder is preferable as the conductive material powder. This is because the conductivity is high, and the specific surface area is large and thus, a larger deformation is achieved. As the carbon powder, Ketjen black is preferable. As the ionic conductive polymer, the same material as that of the polymer compound film **51** is desirable.

The electrode films **52**A and **52**B are formed as follows, for example. A coating in which a conductive material powder and a conductive polymer are dispersed in a dispersion medium is applied to each of both sides of the polymer compound film **51**, and then dried. A film-shaped substance including a conductive material powder and an ionic conductive polymer may be pressure-bonded to each of both sides of the polymer compound film **51**.

The electrode films **52**A and **52**B may each have a multilayer structure, and in that case, it is desirable that each of the electrode films **52**A and **52**B have such a structure that a layer in which particles of a conductive material powder are bound by an ionic conductive polymer and a metal layer are laminated sequentially from the polymer compound film **51** side. This is because an electric potential becomes closer to a further uniform value in an in-plane direction of the electrode films **52**A and **52**B, and superior deformability is obtained. As a material of the metal layer, there is a noble metal such as gold or platinum. The thickness of the metal layer is arbitrary, but is preferably a continuous film so that the electric potential becomes uniform in the electrode films **52**A and **52**B. As a method of forming the metal layer, there is plating, deposition, sputtering, or the like.

The size (width and length) of the polymer compound film **51** may be, for example, freely set according to the size and weight of the lens holding member **43**, or a desirable displacement of the polymer compound film **51**. The displacement of the polymer compound film **51** is set according to a desired movement along the optical axis Z1 of the lens holding member **43**.

(Operation and Effect of Image Pickup Device **2**)

Subsequently, the operation and effect of the image pickup device **2** of the present embodiment will be described.

(1. Operation of Polymer Actuator Elements **441** and **442**)

First, the operation of the polymer actuator elements **441** and **442** will be described with reference to FIGS. **8**A and **8**B. FIGS. **8**A and **8**B each schematically illustrate the operation of the polymer actuator elements **441** and **442**, using a cross-sectional diagram.

At first, a case where a substance including cations and a polar solvent is used as the cationic substance will be described.

In this case, the cationic substance disperses approximately uniformly in the polymer compound film **51** and thus, the polymer actuator elements **441** and **442** in a state of no voltage application become flat without curving (FIG. **8**A). Here, when a voltage applied state is established using the voltage supply section **451** (application of the driving voltage Vd begins), the polymer actuator elements **441** and **442** exhibit the following behavior. When, for example, the predetermined driving voltage Vd is applied between the electrode films **52**A and **52**B so that the electrode film **52**A is at a negative potential whereas the electrode film **52**B is at a positive potential, the cations in a state of being solvated in the polar solvent move to the electrode film **52**A side. At this time, the anions hardly move in the polymer compound film **51** and thus, in the polymer compound film **51**, the electrode film **52**A side swells, while the electrode film **52**B side shrinks. As a result, the polymer actuator elements **441** and **442** curve toward the electrode film **52**B side as a whole, as illustrated in FIG. **8**B. Subsequently, when the state of no voltage application is established by eliminating the potential difference between the electrode films **52**A and **52**B (the application of the driving voltage Vd is stopped), the cationic substance (the cations and polar solvent) localized to the electrode film **52**A side in the polymer compound film **51** diffuses, and return to the state illustrated in FIG. **8**A. Further, when the predetermined driving voltage Vd is applied between the electrode films **52**A and **52**B so that the electrode film **52**A shifts to a positive potential and the electrode film **52**B shifts to a negative potential, from the state of no voltage application illustrated in FIG. **8**A, the cations in the state of being solvated in the polar solvent move to the electrode film **52**B side. In this case, in the polymer compound film **51**, the electrode film **52**A side shrinks while the electrode film **52**B side swells and thus, as a whole, the polymer actuator elements **441** and **442** curve toward the electrode film **52**A side.

Next, a case where an ionic liquid containing liquid cations is used as the cationic substance will be described.

In this case as well, similarly, in the state of no voltage application, the ionic liquid is dispersed in the polymer compound film **51** approximately uniformly and thus, the polymer actuator elements **441** and **442** become flat as illustrated in FIG. **8**A. Here, when a voltage applied state is established by using the voltage supply section **451** (application of the driving voltage Vd begins), the polymer actuator elements **441** and **442** exhibit the following behavior. When, for example, the predetermined driving voltage Vd is applied between the electrode films **52**A and **52**B so that the electrode film **52**B is at a positive potential, whereas the electrode film **52**A is at a negative potential, the cations of the ionic liquid move to the electrode film **52**A side, and the anions hardly move in the polymer compound film **51** which is a cation-exchanger membrane. For this reason, in the polymer compound film **51**, the electrode film **52**A side swells, while the electrode film **52**B side shrinks. As a result, the polymer actuator elements **441** and **442** curve toward the electrode film **52**B side as a whole, as illustrated in FIG. **8**B. Subsequently, when the state of no voltage application is established by eliminating the potential difference between the electrode films **52**A and **52**B (the application of the driving voltage Vd is stopped), the cations localized to the electrode film **52**A side in the polymer compound film **51** diffuse, and return to the state illustrated in FIG. **8**A. Further, when the predetermined driving voltage Vd is applied between the electrode films **52**A and **52**B so that the electrode film **52**A shifts to a positive potential and the electrode film **52**B shifts to a negative potential from the state of no voltage application illustrated in FIG. **8**A, the cations of the ionic liquid move to the electrode film **52**B side. In this case, in the polymer compound film **51**, the electrode film **52**A side shrinks, whereas the electrode film **52**B side swells and thus, as a whole, the polymer actuator elements **441** and **442** curve toward the electrode film **52**A side.

(2. Operation of Image Pickup Device **2**)

Subsequently, the operation of the entire image pickup device **2** will be described with reference to FIGS. **9**A and **9**B. FIGS. **9**A and **9**B each illustrate the operation of the lens module **4** in the image pickup device **2** in a perspective diagram. FIG. **9**A illustrates a state before the operation, and FIG. **9**B illustrates a state after the operation.

In the lens module **4** in the image pickup device **2**, as illustrated in FIG. **3** and FIG. **4** described above as well as FIGS. **9**A and **9**B, the lens **48** becomes movable along the optical axis Z**1**, by driving the lens holding member **43** through use of the pair of polymer actuator elements **441** and **442**. In this way, in the lens module **4**, the lens **48** is driven along the optical axis Z**1** by the driving unit (lens driving unit) employing the polymer actuator elements **441** and **442**.

(3. Technique of Heating Polymer Actuator Elements **441** and **442**)

Subsequently, the technique (heating control) of heating the polymer actuator elements **441** and **442** by the voltage supply section **451**, the control section **452**, and the storage section **453**, which is one of characteristic parts of the present technology, will be described in detail.

First, in the polymer actuator elements **441** and **442**, as illustrated in FIG. **10**, for example, the characteristic of the element declines (deteriorates) in a low temperature environment (here, for example, around −30° C.), compared to a room temperature environment (here, for example, around 25° C.). Specifically, the displacement of the polymer actuator elements **441** and **442** illustrated in the figure (illustrated here as a normalized amplitude) declines, and the working speed decreases. This results from the fact that in the polymer actuator elements **441** and **442**, ion mobility in the polymer compound film **51** (ion exchange resin film) described above decreases in the low temperature environment, compared to the room temperature environment.

Thus, it is conceivable to provide a heat source (heater) outside the element in order to improve the characteristic of such polymer actuator elements **441** and **442** in the low temperature environment. However, provision of such a dedicated heat source separately makes a device configuration large (complicated).

Therefore, in the present embodiment, as will be described below in detail, the voltage supply section **451** supplies the polymer actuator elements **441** and **442** with the heating voltage Vh in addition to the driving voltage Vd, via the fixed electrodes **440**A, **440**B, **440**C, and **440**D. This allows the temperature of the element to rise through heat generated by the polymer actuator elements **441** and **442** themselves (by using the elements themselves as a heat source), without providing the above-mentioned dedicated heat source outside the element separately. As a result, as will be described later, it is possible to improve the characteristics (the displacement or the working speed) of the polymer actuator elements **441** and **442** in the low temperature environment (see, for example, an arrow in FIG. **10**). In other words, the characteristics equal or superior to those in the room temperature environment may be obtained even in the low temperature environment.

Specifically, as schematically illustrated in FIGS. **11**A and **11**B, for example, the voltage supply section **451** of the present embodiment supplies the driving voltage Vd (here, along a Z-axis direction) between the pair of electrode films **52**A and **52**B in each of the polymer actuator elements **441** and **442**. Specifically, the voltage supply section **451** supplies the driving voltage Vd to each of between the fixed electrodes **440**A and **440**B and between the fixed electrodes **440**C and **440**D. On the other hand, the voltage supply section **451** of the present embodiment supplies the heating voltage Vh (here, along the Y-axis direction) in the intra-film direction of each of the electrode films **52**A and **52**B in each of the polymer actuator elements **441** and **442**. Specifically, the voltage supply section **451** supplies the heating voltage Vh to each of between the fixed electrodes **440**A and **440**C and between the fixed electrodes **440**B and **440**D. To be more specific, in the present embodiment, as indicated by an allow in the figure, the voltage supply section **451** selectively supplies the heating voltage Vh to a region (a region on a root side) of the fixing member **42** side (a fixed side) in the polymer actuator elements **441** and **442**. In other words, the voltage supply section **451** supplies the heating voltage Vh along a width direction (here, a Y-axis direction) in the region on the root side of the polymer actuator elements **441** and **442**. This makes it possible to simplify a wiring structure to supply the heating voltage Vh, as compared to a technique in a modification 2 (an example of a technique of supplying the heating voltage Vh from a fixed side along a movable side) that will be described later. In addition, the root region where the displacement is relatively large in each of the polymer actuator elements **441** and **442** is selectively heated and thus, it is possible to heat the element efficiently, as compared to the technique of the modification 2.

FIG. **12** is a flowchart illustrating an example of the technique of heating the polymer actuator elements **441** and **442** according to the present embodiment.

In this technique, at first, as a premise, the voltage supply section **451** supplies the driving voltage Vd to the polymer actuator elements **441** and **442**, thereby causing these polymer actuator elements **441** and **442** to operate (transform) (step S**11**).

Subsequently, an environmental temperature T around the polymer actuator elements **441** and **442** is measured (detected) directly or indirectly by a measuring section (a detecting section) not illustrated (step S**12**). Specifically, the environmental temperature T is detected directly by, for example, an external temperature sensor or the like such as a thermocouple. Alternatively, the environmental temperature T is detected indirectly based on a measured driving current I or a working speed v, by using characteristic data indicating the relationship between the measured driving current I flowing in the element (when the driving voltage Vd is constant) and the environmental temperature T, characteristic data indicating the relationship between the working speed v of the element and the environmental temperature T, or the like (for example, see FIG. **13**). At this time, the measurement of the driving current I may be performed using, for example, an ammeter not illustrated, and the measurement of the working speed v may be performed using, for example, a result of measurement in the Hall elements **47**A and **47**B. In addition, the characteristic data indicating the relationship between the environmental temperature T and the driving current I or the working speed v described above may be held beforehand in, for example, the storage section **453**.

Subsequently, based on the environmental temperature T detected directly or indirectly in this way, the control section **452** first determines (decides) whether or not to supply (whether it is necessary to supply) the heating voltage Vh (step S**13**). Specifically, for example, when the detected environmental temperature T is lower than a predetermined threshold temperature Tth (the environment is the low temperature environment), the control section **452** determines that it is necessary to supply the heating voltage Vh. On the other hand, when the detected environmental temperature T is higher than the threshold temperature Tth mentioned above (the environment is not the low temperature environment), the control section **452** determines that it is not necessary to supply the heating voltage Vh. When the control section **452** determines (decides) that it is not necessary to supply the heating voltage Vh (step S**13**: N), the voltage supply section **451** does not supply the heating voltage Vh (or stops supplying, or lowers the value of the heating voltage Vh) (step S**14**). After that, the flow proceeds to step S**17** to be described later.

On the other hand, when the control section **452** determines (decides) that it is necessary to supply the heating voltage Vh (step S**13**: Y), the control section **452** subsequently determines (decides) the magnitude, waveform, and the like of the heating voltage Vh to be supplied, based on the above-described environmental temperature T (step S**15**). Specifically, the control section **452** determines the magnitude (voltage value) of the heating voltage Vh, whether the heating voltage Vh is a direct current (DC) voltage or an alternating current (AC) voltage, the frequency in the case of the AC voltage, and the like. When the same heating voltages Vh are supplied, the lower the resistance values of the fixed electrodes **440**A, **440**B, **440**C, and **440**D are, the greater the heating value in the polymer actuator elements **441** and **442** is. This is based on a relational expression; Joule heat Q=(driving voltage Vd^2/resistance value R of fixed electrode).

Here, in the arrangement configuration of the fixed electrodes **440**A, **440**B, **440**C, and **440**D illustrated in FIG. **5** described above, a situation schematically illustrated, for example, in FIG. **14**A will be considered. In this situation, as the combination of voltages to be supplied under a condition that driving voltages Vd**1** and Vd**2** at both ends of each of the polymer actuator elements **441** and **442** along the Y-axis direction are supplied to become equal to each other, there are two combinations illustrated in FIGS. **14**B and **14**C as described below. It is to be noted that in the figures, each of Vd, Vd**1**, and Vd**2** represents an arbitrary DC or AC driving voltage (≠0 volt), each of Vh, Vh**1** and Vh**2** represents an arbitrary DC or AC heating voltage (≠0 volt), and the direction of each arrow indicates the direction of a voltage drop (a positive potential difference).

First, in the situation illustrated in FIG. **14**A, when the driving voltages Vd**1** and Vd**2** are equal to each other (Vd**1**=Vd**2**) as mentioned above (when localization of ions in the polymer compound film **51** is prevented from taking place), the following expression (1) is satisfied based on Kirchhoff's law. Here, when the condition of Vd**1**=Vd**2** mentioned above is substituted into this expression (1), Vh**1**=Vh**2** is satisfied. Therefore, there are two combinations of voltages: when Vh**1**=Vh**2**>0 (corresponding to FIG. **14**B) and when Vh**1**=Vh**2**<0 (corresponding to FIG. **14**C). The driving voltage Vd and the heating voltage Vh at this time are arbitrary voltages independent of each other (the respective voltage values and phases may be different). In addition, it is possible to determine the driving voltage Vd and the heating voltage Vh independently, by adjusting the voltages to be supplied to the fixed electrodes **440**A, **440**B, **440**C, and **440**D.

$$Vd1=Vh1+Vd2-Vh2 \tag{1}$$

Further, as the heating voltage Vh, it is possible to use, for example, a DC voltage as illustrated in FIG. **15**A, or an AC voltage as illustrated in FIG. **15**B, but use of the AC voltage is desirable. This is to prevent the localization of ions from occurring along the film thickness direction in the polymer compound film **51** (to prevent undesirable deformation from taking place).

Next, the voltage supply section **451** supplies the heating voltage Vh determined in this way by the control section **452** to the polymer actuator elements **441** and **442** (step S**16**). Subsequently, the control section **452** determines whether or not to terminate the entire heating control illustrated in FIG. **12**, in accordance with, for example, a command from a user, or the like (step S**17**). When it is determined that the heating control is not to be terminated (is to be continued) (step S**17**: N), the flow returns to step S**12** described above, and when it is determined that the heating control is to be terminated (step S**17**: Y), the entire control ends.

FIGS. **16**A and **16**B illustrate an effect of applying the heating voltage Vh according to an example of the present embodiment. FIG. **16**A illustrates a relationship between time (voltage application time) and the displacement of the polymer actuator elements **441** and **442**, and FIG. **16**B illustrates a relationship between the heating voltage Vh and the amplitude during the operation of the polymer actuator elements **441** and **442**. It is to be noted that in this example, the environmental temperature T=−20° C., the driving voltage Vd=1 volt (±1 volt), and a frequency f of the driving voltage Vd=1 Hz. Further, arrows in FIG. **16**A each indicate the timing when the supply of the driving voltage Vd is started.

First, when a case of the heating voltage Vh=0 volt and a case the heating voltage Vh=5 volts are compared to each other, it is found from FIG. **16**A that supplying the heating voltage Vh=5 volts greatly increases the displacement of the polymer actuator elements **441** and **442**, improving the characteristics in the low temperature environment. In addition, it is found from FIG. **16**B that the amplitude of the polymer actuator elements **441** and **442** increases exponentially as the voltage value of this heating voltage Vh increases, improving the characteristics in the low temperature environment further.

In the present embodiment as described above, the driving voltage Vd and the heating voltage Vh are supplied to the polymer actuator elements **441** and **442** and thus, it is possible to increase the temperature of the elements by the heat generation of the polymer actuator elements **441** and **442** themselves, and it is possible to improve the displacement, the working speed, and the like of the elements in the low temperature environment, without providing an external dedicated heat source separately. Therefore, it is possible to improve the characteristics in the low temperature environment, while reducing the size (the weight).

In addition, the heating voltage Vh is supplied selectively to the region (the region on the root side) on the fixing member **42** side (the fixed side) in the polymer actuator elements **441** and **442** and thus, it is possible to simplify the wiring structure to supply the heating voltage Vh, compared to the technique of the modification 2 that will be described later. Moreover, the root region where the displacement is relatively large in the polymer actuator elements **441** and **442** is selectively heated and thus, it is possible to heat the elements efficiently, compared to the technique of the modification 2.

[Modifications]

Subsequently, modifications (modifications 1-3) of the embodiment will be described. It is to be noted that the same elements as those of the embodiment will be provided with the same reference characters as those of the embodiment, and description will be omitted as appropriate.

(Modification 1)

FIGS. **17**A to **17**C each illustrate a configurational example of polymer actuator elements **441** and **442** and fixed electrodes (here, fixed electrodes **440**A and **440**C are taken as examples) according to the modification 1, in a schematic diagram. In the present modification, a heating voltage Vh is supplied (from a fixed side along a movable side) to the entire surface in each of electrode films **52**A and **52**B of each of the polymer actuator elements **441** and **442**, while the configuration of the fixed electrodes in the embodiment described above is basically used.

Specifically, in the example illustrated in FIG. **17**A, the pair of fixed electrodes **440**A and **440**C are provided on the fixing member **42** side (fixed side) on the electrode film **52**B of each of the polymer actuator elements **441** and **442**. In the polymer actuator elements **441** and **442**, a notch **40**C (first notch section) is formed by cutting the whole elements (each film) from an end on the fixed side to the opposite side (to the normal direction of an X-axis), in a region between these fixed electrodes **440**A and **440**C. This makes it possible to supply the heating voltage Vh to the entire surface in each of the electrode films **52**A and **52**B of each of the polymer actuator elements **441** and **442** (from the fixed side along the movable side), while using the configuration of the fixed electrodes in the embodiment described above. In other words, it is possible to supply the heating voltage Vh (from the fixed side along the movable side) to the entire surface in each of the electrode films **52**A and **52**B, while simplifying the configuration of the fixed electrodes, compared to the technique of the modification 2 which will be described later.

In addition, in the example illustrated in FIG. **17**B, similarly, the pair of fixed electrodes **440**A and **440**C are provided on the fixing member **42** side (fixed side) on the electrode film **52**B of each of the polymer actuator elements **441** and **442**. In the polymer actuator elements **441** and **442**, a notch **40**C (second notch section) is formed by selectively cutting the polymer actuator elements **441** and **442**, from the end on the fixed side to the opposite side (to the normal direction of the X-axis), in the region between these fixed electrodes **440**A and **440**C. This makes it possible to supply the heating voltage Vh to the entire surface in each of the electrode films **52**A and **52**B of each of the polymer actuator elements **441** and **442** (from the fixed side along the movable side), while using the configuration of the fixed electrodes in the embodiment described above, like the example in FIG. **17**A. In addition, compared to the example illustrated in FIG. **17**A, the example illustrated in this FIG. **17**B has such an advantage that the notch **40**C is readily formed.

Furthermore, in the example illustrated in FIG. **17**C, similarly, the pair of fixed electrodes **440**A and **440**C are provided on the fixing member **42** side (fixed side) on the electrode film **52**B of each of the polymer actuator elements **441** and **442**. On the electrode film **52**B (**52**A), there is provided a wire (for example, a metal wire) **40**W that establishes an electrical connection between the pair of fixed electrodes **440**A and **440**C from the fixed side via the opposite side (the movable side). This makes it possible to supply the heating voltage Vh to the entire surface in each of the electrode films **52**A and **52**B of each of the polymer actuator elements **441** and **442** (from the fixed side along the movable side), while using a configuration basically similar to that of the fixed electrodes in the embodiment described above. In addition, in the example illustrated in this FIG. **17**C, heating efficiency may be improved and a structure in which the temperature is increased more easily is provided, compared to the examples illustrated in FIGS. **17**A and **17**B, when the same heating voltages Vh are used.

In this way, in the present modification, it is possible to supply the heating voltage Vh to the entire surface in each of the electrode films **52**A and **52**B of each of the polymer actuator elements **441** and **442** (from the fixed side along the movable side) and therefore, the whole elements may be heated. In addition, it is possible to realize a simplified configuration of the fixed electrodes, as compared to the technique of the modification 2 which will be described below.

[Modification 2]

FIGS. **18**A and **18**B each illustrate the technique of applying the driving voltage Vd and the heating voltage Vh according to the modification 2, in a schematic perspective diagram. In the present modification, like the modification 1, the heating voltage Vh is supplied to the entire surface in each of electrode films **52**A and **52**B of each of polymer actuator elements **441** and **442** (from a fixed side along a movable side), while changing the configuration of the fixed electrodes in the embodiment and the modification 1 described above.

Specifically, as schematically illustrated in, for example, FIGS. **18**A and **18**B, the voltage supply section **451** of the present modification first supplies the driving voltage Vd between the pair of electrode films **52**A and **52**B in each of the polymer actuator elements **441** and **442**, as in the embodiment described above. To be more specific, the voltage supply section **451** supplies the driving voltage Vd to each of between fixed electrodes **440**A and **440**B and between fixed electrodes **440**C and **440**D. Further, as in the embodiment described above, the voltage supply section **451** supplies the heating voltage Vh in an intra-film direction of each of the electrode films **52**A and **52**B in each of the polymer actuator elements **441** and **442**. Specifically, the voltage supply section **451** supplies the heating voltage Vh to each of between the fixed electrodes **440**A and **440**C and between the fixed electrodes **440**B and **440**D.

However, unlike the embodiment described above, as indicated by an arrow in the figure, the voltage supply section **451** of the present modification supplies the heating voltage Vh from a region on the fixing member **42** side (a fixed side, or a root side) along the opposite side (a movable section side) in the polymer actuator elements **441** and **442** (here, along an X-axis direction). In other words, the voltage supply section **451** supplies the heating voltage Vh along a direction from the root side to the tip (in a length direction) of the polymer actuator elements **441** and **442**. For this reason, in the present modification, only the fixed electrodes **440**C and **440**D are provided on a fixed section side, and the fixed electrodes **440**A and **440**B are provided on the movable section side (the tip side).

Thus, in the present modification, it is possible to supply the heating voltage Vh to the entire surface in each of the electrode films **52**A and **52**B of each of the polymer actuator elements **441** and **442** (from the fixed side along the movable side), as in the modification 1 described above.

FIGS. **19**A and **19**B illustrate an effect of applying the heating voltage Vh according to an example of the present modification. FIG. **19**A illustrates a relationship between time (voltage application time) and the displacement of the polymer actuator elements **441** and **442**, and FIG. **19**B illustrates a relationship between the heating voltage Vh and the amplitude during the operation of the polymer actuator elements **441** and **442**. It is to be noted that in this example, the environmental temperature T=−20° C., the driving voltage Vd=2 volts (±2 volts), and a frequency f of the driving voltage Vd=1 Hz. In addition, an arrow in FIG. **19**A indicates the timing when the supply of the driving voltage Vd is started.

First, when a case where the heating voltage Vh=0 and a case where the heating voltage Vh=4 are compared to each other, it is found from FIG. **19**A that supplying the heating voltage Vh=4 volts greatly increases the displacement of the polymer actuator elements **441** and **442**, improving the characteristics in the low temperature environment. In addition, it is found from FIG. **19**B that the amplitude of the polymer actuator elements **441** and **442** increases exponentially as the voltage value of this heating voltage Vh increases, improving the characteristics in the low temperature environment further.

In this way, in the present modification, it is possible to supply the heating voltage Vh to the entire surface in each of the electrode films **52**A and **52**B of each of the polymer actuator elements **441** and **442** (from the fixed side along the movable side) as well and thus, the whole elements may be heated.

[Modification 3]

FIGS. **20**A and **20**B each illustrate a technique of applying a driving voltage Vd and a heating voltage Vh according to the modification 3, in a schematic perspective diagram. In the present modification, unlike the embodiment and the modifications 1 and 2 described so far, the heating voltage Vh is applied between electrode films **52**A and **52**B of each of polymer actuator elements **441** and **442**.

Specifically, as schematically illustrated in FIGS. **20**A and **20**B, for example, a voltage supply section **451** of the present modification first supplies a driving voltage Vd between the pair of electrode films **52**A and **52**B in each of the polymer actuator elements **441** and **442**, as in the embodiment and the like described above. Specifically, in the present modification, the voltage supply section **451** supplies the driving voltage Vd between fixed electrodes **440**C and **440**D.

However, unlike the embodiment and the like described above, as indicated with an arrow in the figure, the voltage supply section **451** of the present modification also supplies the heating voltage Vh, in addition to the driving voltage Vd, between the pair of electrode films **52**A and **52**B in each of the polymer actuator elements **441** and **442**. Specifically, in the present modification, the voltage supply section **451** also supplies the heating voltage Vh between the fixed electrodes **440**C and **440**D. In this way, in the present modification, both the driving voltage Vd and the heating voltage Vh are supplied between the pair of electrode films **52**A and **52**B in each of the polymer actuator elements **441** and **442**.

To be more specific, as illustrated in each of FIGS. **21**A and **21**B, for example, the voltage supply section **451** supplies the heating voltage Vh and the driving voltage Vd by superimposing the heating voltage Vh of a high-frequency AC voltage (for example, around 1 kHz) on the driving voltage Vd of a DC voltage or an AC voltage.

Thanks to such a configuration, in the present modification, the heating voltage Vh of the high frequency on a level that does not allow the polymer actuator elements **441** and **442** to follow (deform) is superimposed on the driving voltage Vd and thus, it is possible to obtain effects similar to those in the embodiment and the like described above. In other words, it is possible to increase the temperature of the element through heat generation by the polymer actuator elements **441** and **442** themselves, and improve the displacement or the working speed of the elements in the low temperature environment, without providing an external dedicated heat source separately. Therefore, it is possible to improve the characteristics in the low temperature environment while reducing the size (weight). In addition, in the present modification in particular, as illustrated in FIGS. **20**A and **20**B, only the two fixed electrodes **440**C and **440**D may be provided and thus, implementation with a more simple configuration is possible, and further downsizing (weight reduction) is allowed, as compared to the above-described embodiment and the like in which the four fixed electrodes **440**A, **440**B, **440**C, and **440**D are provided.

[Other Modifications]

The present technology has been described by using the embodiment and the modifications, but the present technology is not limited to these embodiment and the like and may be variously modified.

For example, the technique of supplying the driving voltage Vd and the heating voltage Vh and their waveforms and the like are not limited to those described in the embodiment and the like, and other techniques and waveforms may be employed. In addition, as the voltage supply section **451** described in the embodiment and the like, a part supplying the driving voltage Vd and a part supplying the heating voltage Vh may be provided separately, or the parts supplying these two types of voltage may be commonized (unified) and provided. However, when the part supplying the driving voltage Vd and the part supplying the heating voltage Vh are provided separately, it is desirable to provide a driving electrode and a heating electrode separately. This is because if these electrodes are commonized, independent voltages may not be supplied.

Further, the embodiment and the like have been described for the case where the pair of polymer actuator elements are provided, but the polymer actuator elements may not be a pair, and one or three or more polymer actuator elements may be provided.

Furthermore, the shape of the polymer actuator element is not limited to that in each of the embodiment and the like and also, the layered structure thereof is not limited to that described in each of the embodiment and the like and may be modified as appropriate. In addition, the shape, material, and the like of each member in the lens module (driving unit) are not limited as well to those described in the embodiment and the like.

Moreover, the embodiment and the like have been described by taking the lens driving unit that drives the lens along the optical axis as an example of the driving unit according to the embodiment of the present disclosure, but the driving unit is not limited to this case. In other words, the driving unit according to the embodiment of the present disclosure is applicable to, for example, a driving unit that drives a diaphragm or the like (see Japanese Unexamined Patent Application Publication No. 2008-259381 and the like), other than such a lens driving unit. In addition, the driving unit, the lens module, and the image pickup device according to the embodiment of the present disclosure are applicable to various kinds of electronic device, other than the portable telephone described in the above embodiment and the like.

The present disclosure contains subject matter related to that disclosed in Japanese Priority Patent Application JP 2010-181716 filed in the Japan Patent Office on Aug. 16, 2010, the entire content of which is hereby incorporated by reference.

It should be understood by those skilled in the art that various modifications, combinations, sub-combinations and alterations may occur depending on design requirements and other factors insofar as they are within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. A driving unit comprising:

one or more polymer actuator elements comprising, respectively, a polymer material;

a voltage supply section configured to supply a driving voltage and a heating voltage, distinct from the driving voltage, to at least one of the one or more polymer actuator elements, wherein a first polymer actuator element of the one or more polymer actuator elements includes a pair of electrode films, and wherein the polymer material of the first polymer actuator element comprises a polymer film between the pair of electrode films;

a first electrode pair having first and second electrodes disposed on respective electrode films of the pair of electrode films; and

a second electrode pair having first and second electrodes disposed on respective electrode films of the pair of electrode films and spaced from the first electrode pair, wherein the voltage supply section supplies the driving voltage between the first and second electrodes of the first electrode pair and between the first and second electrodes of the second electrode pair, and wherein the voltage supply section supplies the heating voltage between the first electrodes of the first and second electrode pairs and between the second electrodes of the first and second electrode pairs.

2. The driving unit according to claim **1**, wherein the voltage supply section is configured to supply the heating voltage in an intra-film direction of each of the electrode films.

3. The driving unit according to claim **2**, further comprising:

a fixing member fixing one end of the first polymer actuator element.

4. The driving unit according to claim **3**, wherein the voltage supply section is configured to supply the heating voltage selectively to a region on the fixing member side in the first polymer actuator element.

5. The driving unit according to claim **3**, further comprising:

a plurality of fixed electrodes disposed on the fixing member side on each of the electrode films, the voltage supply section configured to supply the plurality of fixed electrodes with the heating voltage,

wherein the first polymer actuator element has a first notch section formed from an end on the fixing member side in a region between the plurality of fixed electrodes toward an opposite side thereof, by cutting each film.

6. The driving unit according to claim **3**, further comprising:

a plurality of fixed electrodes disposed on the fixing member side on each of the electrode films, the voltage supply section configured to supply the plurality of fixed electrodes with the heating voltage,

wherein the first polymer actuator element has a second notch section formed from an end on the fixing member side in a region between the plurality of fixed electrodes toward an opposite side thereof, by cutting the pair of electrode films selectively.

7. The driving unit according to claim **3**, further comprising:

a plurality of fixed electrodes disposed on the fixing member side on each of the electrode films, the voltage supply section configured to supply the plurality of fixed electrodes with the heating voltage; and

a wiring making an electrical connection between the plurality of fixed electrodes, from the fixing member side via an opposite side thereof.

8. The driving unit according to claim **3**, wherein the voltage supply section is configured to supply the heating voltage from the fixing member side along an opposite side thereof, in the first polymer actuator element.

9. The driving unit according to claim **1**, wherein the voltage supply section is configured to supply both the driving voltage and the heating voltage between the pair of electrode films.

10. The driving unit according to claim **9**, wherein the voltage supply section is configured to supply a heating voltage of a high-frequency alternating current voltage, superimposed on the driving voltage.

11. The driving unit according to claim **1**, wherein the heating voltage is an alternating current voltage.

12. The driving unit according to claim **1**, further comprising:

a control section configured to determine whether or not to supply the heating voltage, as well as a magnitude and a waveform of a heating voltage to be supplied, based on an environmental temperature detected directly or indirectly.

13. The driving unit according to claim **1**, wherein the driving unit is configured as a lens driving unit driving a lens.

14. The driving unit according to claim **3**, wherein the first polymer actuator element includes a fixed side and a movable side and wherein the first and second electrode pairs are disposed on respective electrode films of the pair of electrode films on the fixed side of the first polymer actuator element.

15. A lens module comprising:

a lens; and

a driving unit driving the lens,

wherein the driving unit includes

one or more polymer actuator elements comprising, respectively, a polymer material,

a voltage supply section configured to supply a driving voltage and a heating voltage, distinct from the driving voltage, to at least one of the one or more polymer actuator elements, wherein a first polymer actuator element of the one or more polymer actuator elements includes a pair of electrode films, and wherein the polymer material of the first polymer actuator element comprises a polymer film between the pair of electrode films;

a first electrode pair having first and second electrodes disposed on respective electrode films of the pair of electrode films; and

a second electrode pair having first and second electrodes disposed on respective electrode films of the pair of electrode films and spaced from the first electrode pair, wherein the voltage supply section supplies the driving voltage between the first and second electrodes of the first electrode pair and between the first and second electrodes of the second electrode pair, and wherein the voltage supply section supplies the heating voltage between the first electrodes of the first and second electrode pairs and between the second electrodes of the first and second electrode pairs.

16. The lens module according to claim **15**, wherein the first polymer actuator element includes a fixed side and a movable side and wherein the first and second electrode pairs are disposed on respective electrode films of the pair of electrode films on the fixed side of the first polymer actuator element.

17. An image pickup device comprising:

a lens;

an image pickup element acquiring an image pickup signal of image formation by the lens; and

a driving unit driving the lens,

wherein the driving unit includes

one or more polymer actuator elements comprising, respectively, a polymer material,

a voltage supply section configured to supply a driving voltage and a heating voltage, distinct from the driving voltage, to at least one of the one or more polymer actuator elements, wherein a first polymer actuator element of the one or more polymer actuator elements includes a pair of electrode films, and wherein the polymer material of the first polymer actuator element comprises a polymer film between the pair of electrode films;

a first electrode pair having first and second electrodes disposed on respective electrode films of the pair of electrode films; and

a second electrode pair having first and second electrodes disposed on respective electrode films of the pair of electrode films and spaced from the first electrode pair, wherein the voltage supply section supplies the driving voltage between the first and second electrodes of the first electrode pair and between the first and second electrodes of the second electrode pair, and wherein the voltage supply section supplies the heating voltage between the first electrodes of the first and second electrode pairs and between the second electrodes of the first and second electrode pairs.

18. The image pickup device according to claim **17**, wherein the first polymer actuator element includes a fixed side and a movable side and wherein the first and second electrode pairs are disposed on respective electrode films of the pair of electrode films on the fixed side of the first polymer actuator element.

* * * * *